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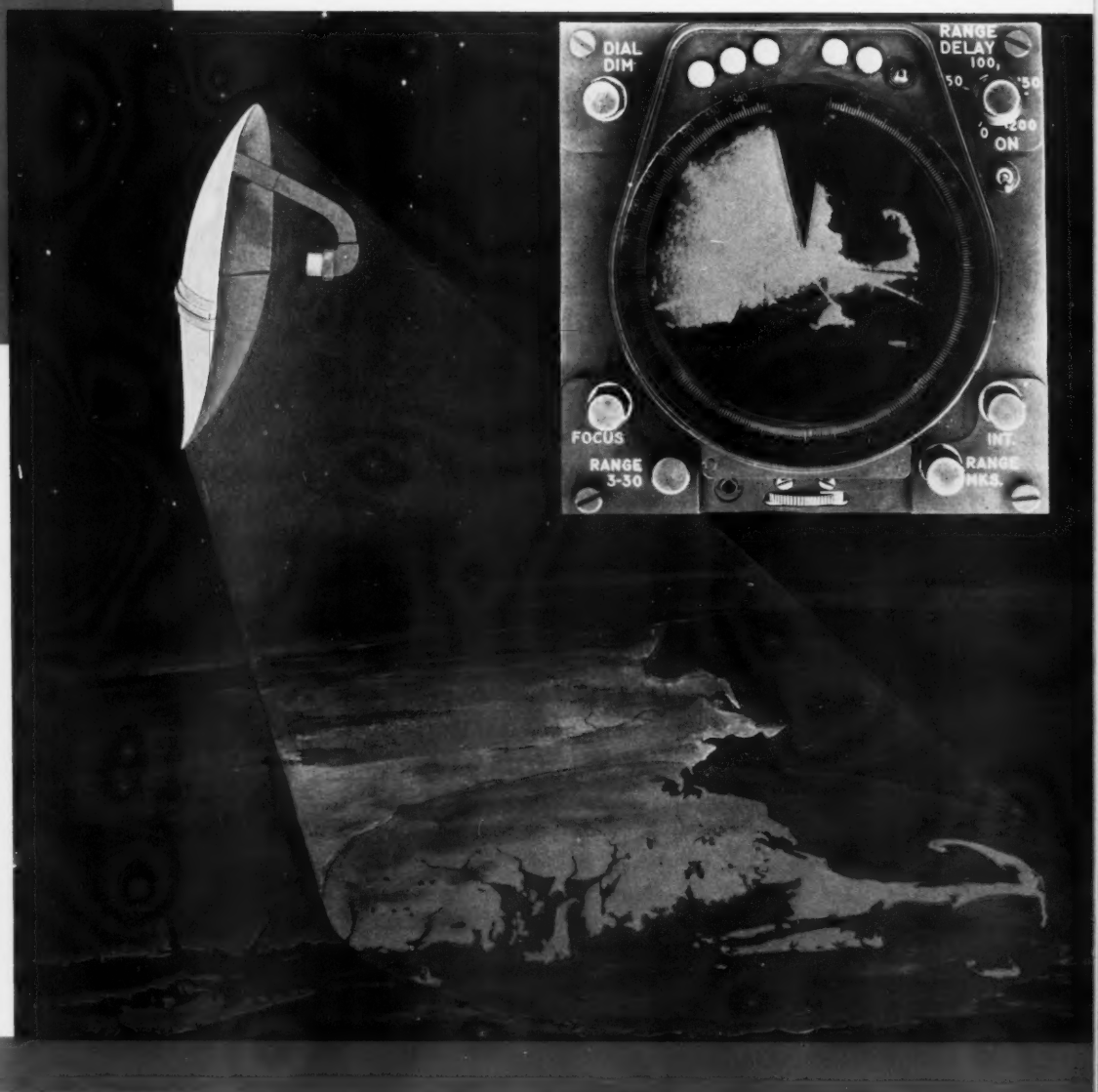

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May, 1956

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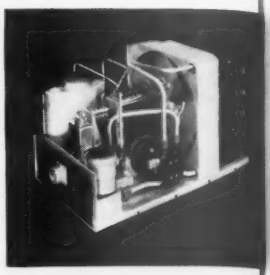

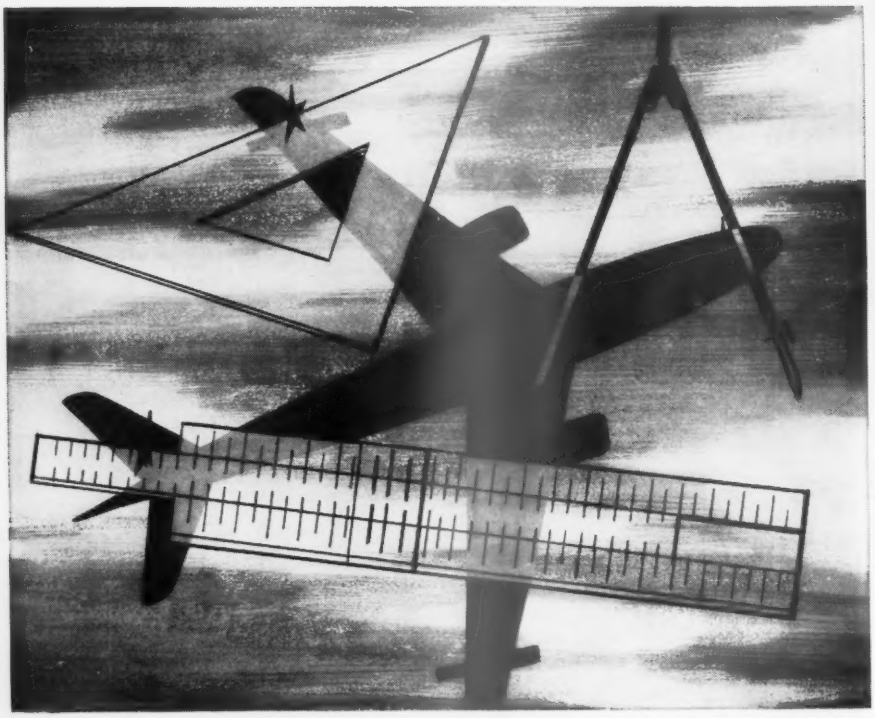

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Write for Aviation Products Catalog, Bulletin 3

Aeronautical Engineering Review

Vol. 15—No. 5 May, 1956

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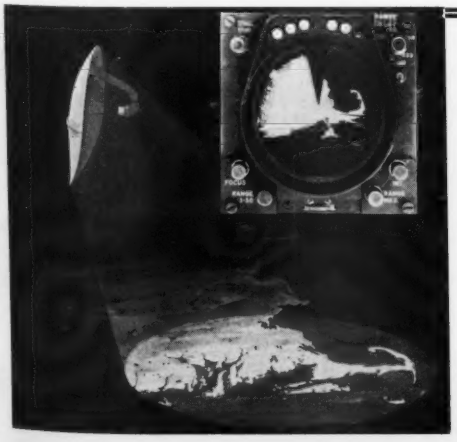

Cover—Sketch of Cape Cod (Mass.) area is compared with its actual image (***upper right***) on the oscilloscope of Sperry Gyroscope Company's APN-59 radar, now in production for use on Air Force transports. Said to be the first air-borne radar with dual antennas, the 150-lb. unit can be used for search and surveillance, storm detection, and other all-weather navigation procedures at ranges from 3 to 240 miles. It has a 5-in. viewing screen. (***Drawing by Ken Crawford.***)

Published Monthly by the

Institute of the Aeronautical Sciences, Inc.

2 East 64th Street, New York 21, N.Y.

Western Office: 7660 Beverly Blvd., Los Angeles 36, Calif.

OPERATION HUNTER-KILLER

1600 hours. U.S.S. Tarawa launches 2 Grumman S2 airplanes to sink an "enemy" sub stalking HUK Group from an area 70 miles away during recent Anti-submarine Warfare Operations in the Caribbean Sea.

AIR ATTACK FROM DAVY JONES

0900. No datum. All night planes and destroyers have fed reports to Tarawa's darkened Combat Intelligence Center. The plot boards show only friendly shipping.

I.A.S. News Notes

May 1956

PROCEEDINGS of the Fifth International Aeronautical Conference, held in Los Angeles last June, have been printed in book form and are now available from the Publications Department of the IAS, 2 East 64th Street, New York 21, N.Y. Bound in board covers, the 560-page volume sells for $15.00 to IAS members and $20.00 to nonmembers. It contains the complete papers and discussions presented at this joint meeting of the Institute and The Royal Aeronautical Society. All illustrations are included with the 18 papers.

FOR MEMBERS who may be interested, the Institute still has a limited number of copies of the Proceedings of the Second International Aeronautical Conference, which was held in New York in 1949. While the supply lasts, these bound volumes may be obtained at $5.00 each.

PLANS ARE SHAPING UP for the 1956 National Turbine-Powered Air Transportation Meeting of the Institute August 15-17 in San Diego, California. Five technical sessions, two luncheons, and a dinner will fill the program. The first day will be devoted to papers and a panel discussion on "The Introduction of Turbine-Powered Transports into Scheduled Service." General topics for the next day will be "Noise Associated with Turbine-Powered Transports" and "Operational Considerations with Turbine-Powered Transports." On the final day, the subject will be "The Future for Mass Air Transportation." Headquarters will be in the U.S. Grant Hotel, and reservations should be addressed directly to the hotel.

THE INSTITUTE was represented at an AGARD Symposium on "The History of German Guided-Missile Development" held in Munich, Germany, last month. Director S. Paul Johnston and Secretary Robert R. Dexter attended with the American Delegation.

NATIONAL MEETINGS CALENDAR

June 18-21 Summer Meeting, IAS Building, Los Angeles, California.
June 20 Annual Summer Banquet, Biltmore Hotel, Los Angeles, Calif.
Aug. 15-17 Turbine-Powered Air Transportation Meeting, U. S. Grant Hotel, San Diego, California. Exhibits at IAS Building.

JOINT MEETINGS CALENDAR

May 14-16 IRE National Conference on Aeronautical Electronics, Biltmore Hotel, Dayton. IAS Session on Human Engineering.
Aug. 20-21 National Telemetering Conference, Biltmore Hotel, Los Angeles. Cosponsored with AIEE, IRE, and ISA.

REGIONAL STUDENT CONFERENCES.

May 3,4 West Coast Conference, IAS Building, Los Angeles. Sponsored by the Los Angeles Section.
May 10 Detroit Section Conference, University of Detroit, Detroit, Mich.

I.A.S. News Notes (con't.)

SECTION MEETINGS CALENDAR

May 3 Atlanta Section: Officers Club, NAS, Chamblee, Ga. Dinner 7 p.m. "Progress in Research on Some Aircraft Operational Problems" by Melvin N. Gough of Langley Aeronautical Laboratory, NACA.

May 3, 4 Los Angeles Section: Student Conference and Banquet, IAS Building. Undergraduate papers May 3, graduate papers May 4. Presentation of awards and speech by Lt. Gen. Laurence C. Craigie, 7 p.m. on May 4.

May 8 Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Experimental Investigation of Catastrophic Failure in Aircraft Structures" by William J. Conway.

May 8 San Diego Section: IAS Building, 8 p.m. "Navy Maintenance Problems" by Capt. Paul Burr, USN, Staff ComAirPac.

May 8 Washington Section: Occidental Restaurant. Reception 6 p.m., Dinner 6:45 p.m., Meeting 8 p.m. "Our Research and Development Shortages" by H. Guyford Stever, former Chief Scientist, USAF.

May 9 Niagara Frontier Section: Park Lane Hotel, Buffalo. Dinner 7:30 p.m. Panel Discussion, "The Role of the Engineer in Society," by Ira G. Ross of Cornell Aeronautical Laboratory and Leston Faneuf of Bell Aircraft Corp. Joseph Schister, Univ. of Buffalo, Moderator.

May 10 Los Angeles Section: IAS Building. Reception 6 p.m., Dinner 7 p.m., Meeting 8 p.m. "The IGY Program and the Satellite" by Joseph Kaplan.

May 12 New York Section: Tour of Brookhaven National Laboratory, AEC, near Coram, Long Island. Registration 10:30 a.m., Briefing 11 a.m., Luncheon 12 noon, Tour 1 p.m.

May 17 San Francisco Section: Confidential Meeting at Ames Aeronautical Laboratory, NACA, 8 p.m. "Supersonic Propulsion Systems" by Abe Silverstein of Lewis Flight Propulsion Laboratory, NACA.

May 18 Los Angeles Section: Air Youth Day in cooperation with the California Aviation Education Association. IAS Building. Reception 6 p.m., Dinner 7 p.m., Program 8 p.m.

May 18 Los Angeles Section: Historical Branch Meeting, IAS Building, 8 p.m. "Design Considerations of Early Military Aircraft" by R. L. Bliss and R. P. Johnston.

May 19 San Diego Section: Spring Dance, IAS Building, 9 p.m.

May 22 Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Winds Aloft as a Factor in Aeronautical Problems" by Robert Rapp.

May 23 St. Louis Section: Congress Hotel. Dinner 6 p.m., Meeting 8 p.m. Talks by Major Edmund E. Novotny and Capt. Jess R. Totten of the Air Force Special Weapons Center, Kirtland AFB.

May 24 San Diego Section: IAS Building, 8 p.m. "The Producibility Barrier" by Messrs. Monahan and Morgan of Convair.

May 28 Los Angeles Section: Field Trip to Hughes Aircraft factory. Confidential clearance required.

June 5 Dayton Section: Levitt's Manor, 6:30 p.m. "Analog Computers as an Engineering Tool" by J. S. Randolph of Goodyear Aircraft Corp.

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IAS News

A Record of People and Events of Interest to Institute Members

The National Summer Meeting

Technical Sessions, Banquet, and Field Trip Fill Los Angeles Program Next Month

THE INSTITUTE'S National Summer Meeting for 1956 will be held in Los Angeles June 18–21, with headquarters at the IAS Building, 7660 Beverly Boulevard. All technical sessions will be held there.

Three days of technical sessions, during which about 25 papers will be delivered, will be followed by the Annual Banquet on Wednesday evening, June 20, in the Biltmore Hotel. The fourth day will be devoted to a field trip to March Air Force Base, Calif., and a confidential session in the evening.

About 1,100 members and guests are expected to attend the dinner, which has been planned as a tribute to Theodore von Kármán, an Honorary Fellow of the Institute, who marks his 75th birthday on May 11. Hugh L. Dryden, Director of the National Advisory Committee for Aeronautics, who has known the great scientist for many years, will deliver the principal address. President Edward R. Sharp will be Toastmaster.

Dr. von Kármán, who retired in 1949 from the faculty of California Institute of Technology where he was Director of the Guggenheim Aeronautical Laboratory, is now Chairman of the Advisory Group for Aeronautical Research and Development of the North Atlantic Treaty Organization. He is Chairman Emeritus of the Air Force Scientific Advisory Board.

Several professional and scientific organizations with which Dr. von Kármán is affiliated have been invited to send representatives to the dinner.

Alfred J. Carah, AFIAS, of Douglas Aircraft Company, Inc., is Chairman of the Summer Meeting Committee. The other committee members are C. R. Cantrell, Jr., William R. Dunbar, Syd Fasken, Carl Gazley, Jr., Frederick H. Green, R. J. Gunkel, Donald A. Justice, and Donald D. Warner.

The Los Angeles Section, headed by George R. Mellinger, is assisting in arrangements.

The tentative program of technical sessions follows:

Monday, June 18—Morning and afternoon sessions on "Aerodynamic Heating," with Clark B. Millikan and William F. Ballhaus as Chairmen. The topic of the evening session will be "Operation of Large Turbine-Powered Aircraft." Edward F. Burton will preside.

Tuesday, June 19—Morning session, "Low-Speed Flight," with Philip A. Colman in the chair. Afternoon session on "Economics" with L. Eugene Root as Chairman. The evening session will be devoted to a discussion of "Sociological Influences of Aviation." Robert E. Gross will be Chairman.

Wednesday, June 20—Morning session, "Advanced Techniques," Milton U. Clauser, Chairman. Afternoon session (confidential) on "Supersonic Propulsion for Aircraft and Missiles, 1960–1965." Roy E. Marquardt will preside. The banquet will be held in the evening.

George R. Mellinger

Hugh L. Dryden

Thursday, June 21—Field Trip to March AFB (confidential). In the evening, five Boeing engineers will describe the "Development of the B-52" at a confidential session. R. H. Rice will preside.

The all-day field trip, limited to 400 visitors, will require confidential security clearance. The day will start at 6:00 a.m. with breakfast at the IAS Building, and at 7:00 a.m. the busses will depart on the 2-hour run to March AFB.

Alfred J. Carah

IAS *Journal* Honors von Kármán

Theodore von Kármán, an Honorary Fellow of the Institute, marks his 75th birthday on May 11.

In an extraordinary gesture of congratulation, the May issue of the JOURNAL OF THE AERONAUTICAL SCIENCES has been devoted entirely to papers by 12 of his former students summarizing the present status of the several technical fields to which Dr. von Kármán contributed.

In a foreword signed by Robert R. Dexter, Hugh L. Dryden, William R. Sears, and Frank Wattendorf, the Institute thanks him for "his inspiring leadership and friendship for the past 30 years" and notes that he is still active in creative scientific work and in stimulating the reviving aeronautical sciences of the NATO countries as Chairman of NATO's Advisory Group for Aeronautical Research and Development (AGARD).

"No other man has had so great an impact on the development of aeronautical science in this country," writes the JOURNAL. "Hundreds of young men became his students and scientific collaborators and were inspired to greater creative effort. They were taught by him to analyze technical problems in terms of fundamental physical concepts and to apply mathematical analysis, striving for simplicity but retaining adequate accuracy for engineering purposes. Many of these men are now leaders of aeronautical science and engineering.

"Von Kármán's influence has by no means been confined to the United States. He has promoted international cooperation and has collaborated in scientific work with men from many nations. Throughout the world, one finds thousands of men who treasure his friendship and kindly counsel."

Dr. von Kármán came to the United States from Germany in 1926, on the invitation of the Daniel Guggenheim Fund for the Promotion of Aeronautics, to lecture at many universities and research institutions. A few years later he established his residence in California, becoming an American citizen in 1936. Professor Emeritus of California Institute of Technology and Chairman Emeritus of the Air Force Scientific Advisory Board, he has won many honors, the most recent being the Daniel Guggenheim Medal for 1955.

The 12 papers in the "von Kármán" issue were written by M. A. Biot, Francis H. Clauser, Pol Duwez, Arthur T. Ippen, Arnold M. Kuethe, C. C. Lin, Frank E. Marble, W. Bailey Oswald, W. Duncan Rannie, William R. Sears, E. E. Sechler, and H. J. Stewart. To avoid delays, the authors were chosen from among the scientist's former students now living in the United States. Clark B. Millikan contributed a biographical sketch of Dr. von Kármán.

AGARD Meetings in Rome

Several members of the Institute attended committee meetings of NATO's Advisory Group for Aeronautical Research and Development in Rome, Italy, February 20–25.

Among speakers and observers at meetings of the Flight Test Panel and the Wind Tunnel and Model Testing Panel were Ira H. Abbott, Donald D. Baals, and Melvin N. Gough, of the National Advisory Committee for Aeronautics; Courtland D. Perkins, of Princeton University; Leon H. Schindel, of Massachusetts Institute of Technology; and Hermann Schlichting, of the Technical University of Braunschweig, Germany.

Eugene B. Jackson, Chief of NACA's Division of Research Information, was Chairman of the meeting of the Documentation Committee. John J. Glennon, IAS Librarian, attended the Documentation sessions as an observer.

Frank L. Wattendorf, Director of AGARD, and Deryck C. Smith, also of the AGARD Secretariat, were present in their official capacities.

Altogether, 134 aeronautical engineers, scientists, and military officers from various NATO countries attended the sessions in Rome.

Harry Guggenheim Honored

Harry F. Guggenheim, an Honorary Member, Founder, and Benefactor of the Institute, has been named an Elder Statesman of Aviation by the Board of Directors of the National Aeronautic Association.

The eleventh IAS member to be so honored, Mr. Guggenheim was cited for "giving generously of his time and abilities over a long period and making contributions of enduring value to aeronautics."

A leader in aeronautics for 30 years, he gave financial support to pioneer work in jet propulsion, rockets, aviation safety, instrument flying, and meteorology, and to the first scheduled commercial air line in the United States. As President of the Daniel Guggenheim Fund for the Promotion of Aeronautics, he helped to establish six schools of aeronautical engineering in American universities. In 1928 he established the Daniel Guggenheim Medal. He was appointed to the National Advisory Committee for Aeronautics in 1929 and served until 1938.

Mr. Guggenheim served as a Naval aviator in World War I and was recalled to active duty in 1942. He was a Captain when he left the Navy.

Burden on Lockheed Board

William A. M. Burden, a member of the IAS Council and Past President, has been elected to the Board of Directors of Lockheed Aircraft Corporation. Senior partner in a New York investment firm, Mr. Burden has been Assistant Secretary of Commerce for Air, a member of the National Advisory Committee for Aeronautics, and a Special Assistant for Research and Development to the Secretary of the Air Force.

New Division of ARDC

The Air Research and Development Command of the Air Force has established a new Technical Industrial Relations Division to serve as the initial contact between potential contractors and the ARDC.

Warren L. Baker, MIAS, former Chief of the Systems Division of the ARDC Office of Analysis and Evaluation, has been named Chief of the new division. His office is in the Sun Building, Headquarters ARDC, Baltimore.

The Technical Industrial Relations Division places special emphasis upon obtaining scientific and technical contributions from industrial and private research and development agencies that have not previously been ARDC contractors. It conducts preliminary evaluation of ideas presented and then recommends further action by the ARDC branch concerned.

Thiokol Chemical Corporation Joins the Institute

Thiokol Chemical Corporation, of Trenton, N.J., has joined the Institute of the Aeronautical Sciences as a Corporate Member.

The company was founded in 1929 as a result of the discovery of "Thiokol" synthetic rubber, an organic polysulfide elastomer with unusual oil- and solvent-resistant properties. Early in the 1930's when it became necessary to seal the wing tanks of the early Pan American Clippers, Thiokol synthetic rubber was used as a gasoline sealer. Since that time, the art of sealing integral fuel tanks in planes has been much advanced as a result of development work conducted by the large aircraft companies and Government laboratories. Now each large transport plane utilizes approximately 300 lbs. of Thiokol synthetic rubber as a sealer for various components.

Thiokol rubber compounds are now used to seal wing tanks, electrical connectors, windshields, and pressurized cabins; as repair sealers on aircraft; as aerodynamic smoothers; and in the form of protective coatings for leading edges of wings. They also are used in gaskets and diaphragms.

The latest activities of Thiokol in aviation lie in the field of development, design, and construction of solid-propellant rocket motors. On the basis of fundamental information developed by the Jet Propulsion Laboratory of California Institute of Technology, Thiokol entered the field of solid rocketry in 1948. Since that time, the company has expanded its facilities in this field to three divisions, located at Huntsville, Ala.; Marshall, Tex.; and Elkton, Md. At these facilities, Thiokol has conducted work on projects such as the Hughes Falcon, which is powered by a Thiokol solid-propellant motor, and on a number of advanced propulsion systems which cannot be mentioned because of security considerations. Thiokol's activities in this field have led to the development of some of the largest solid-propellant motors in the world, as well as some of the smallest.

In addition to its rocket facilities, Thiokol operates plants at Trenton, N.J., and Moss Point, Miss., for the production of synthetic rubbers, plastics, and chemicals.

Weber Aircraft Joins IAS as a Corporate Member

Weber Aircraft Corporation, of Burbank, Calif., has joined the Institute of the Aeronautical Sciences as a Corporate Member. Active in the aviation industry for 15 years, the company is engaged in the design and manufacture of interior equipment and components for aircraft.

The expanding activity in aeronautical research, design, and development at Weber includes projects on advanced concepts in escape systems, studies on new approaches to pilot pressure suits, design of a general-purpose analog computer and other electronic devices, and, of prime interest, the complete design and development of an advanced type of vertically rising airplane.

The STOL airplane design, under development by Weber for 2 years, engages particular interest by combining the capabilities of rotary-wing and fixed-wing aircraft without the basic penalties usually accepted for this increased versatility. This results from the adaptation of the deflected slipstream aerodynamic principle to a conventional propeller-driven aircraft configuration with the necessary power ratio to meet present-day speed requirements.

The history of Weber Aircraft Corporation covers a broad experience in aircraft component manufacturing, from production and assembly of air-frame components, glider wings, complete power packs, and many other items, to the design and production of pilot-ejection systems, all types of cabin equipment and furnishings, and many other air-borne items used in military and commercial aircraft.

Weber's main plant encompasses a complete manufacturing and engineering facility which produced over 450 Lockheed P-38's and military versions of the Lodestar during World War II.

Necrology

Joseph N. Cariola

Joseph Nino Cariola, MIAS, a Senior Design Engineer with Convair, A Division of General Dynamics Corporation, died on January 29. He was 57 years old.

A native of Italy, Mr. Cariola became an American citizen in 1926. He joined Convair in 1941 and lived in San Diego, Calif.

A. G. Lamplugh

Word has been received of the death of Alfred Gilmer Lamplugh, MIAS, of London, England, in December. He was 60 years old.

Captain Lamplugh, who learned to fly in 1915, served in the Royal Flying Corps during the first World War and later in the Royal Air Force. He was a Fellow of the Royal Aeronautical Society, a member of the Royal Aero Club, and a former President of the London Gliding Club.

Licensed as a pilot, navigator, radio operator, and ground engineer, Captain Lamplugh participated in several survey flights to establish British air-line routes. Subsequently he was a Warden and Deputy Master of the Guild of Air Pilots and Air Navigators of the British Empire and Chairman of the Air Registration Board's Survey Committee.

Since 1930, Captain Lamplugh had been Underwriter and Principal Surveyor of The British Aviation Insurance Company Limited. He was a member of the firm's Board of Directors.

William B. Stout

William Bushnell Stout, FIAS, who designed the Ford Tri-Motor airplane in 1925, died of a heart attack at his home in Phoenix, Ariz., on March 20. He was 76 years old.

Born in Quincy, Ill., Mr. Stout graduated from the University of Minnesota in 1904 with a degree in mechanical engineering. He started his business career as a feature writer on the *St. Paul Dispatch*, advising boys how to make aviation toys. Subsequently he organized the Illinois Model Aeroplane Club and became aviation editor of the *Chicago Tribune*. In 1912 he founded *Aerial Age*, one of the first aviation magazines.

In 1918, while Assistant to the Chief Engineer of the U.S. Army Air Service,

William B. Stout

Mr. Stout developed the first cantilever-wing monoplane. He then established his own laboratory in Detroit and developed a commercial monoplane. In 1922 he developed an all-metal torpedo plane for the Navy.

In 1925, Mr. Stout sold his idea for an all-metal passenger transport to Henry Ford and became head of the Stout Metal Airplane Company Division of Ford Motor Co. While still with Ford, he started the first all-passenger air line in this country, with service between Detroit and Grand Rapids, Mich. A few years later he sold out to a predecessor of United Air Lines, Inc. He also was a founder of Northwest Airlines.

In 1931, Mr. Stout designed for Ford a "flivver" of the air, intended to sell for less than $2,000. It was a two-seat, all-metal monoplane called the SkyCar. This was not produced, however.

Mr. Stout served as President of the Society of Automotive Engineers in 1935.

In recent years, he operated the Stout Research Laboratories in Phoenix. He is survived by his widow, Alma Raymond Stout, and a daughter.

NEWS OF MEMBERS

▸ **J. L. Atwood** (F), President of North American Aviation, Inc., and Past President of the IAS, has been appointed to the Industry Consulting Committee of the National Advisory Committee for Aeronautics.

▸ **Raymond L. Bisplinghoff** (AF), Professor of Aeronautical Engineering at Massachusetts Institute of Technology, is a new member of the NACA's Committee on Aircraft Construction.

▸ **William A. M. Burden,** Past President, has been given the Cross of Chevalier of the French Legion of Honor. Mr. Burden, who is President of the Museum of Modern Art, New York, served as Cochairman of "Salute to France," a series of cultural events presented in Paris last year.

▸ **John L. Cooley** (M), Vice-President of California Research Corporation, has been appointed Chairman of the NACA's Subcommittee on Aircraft Fuels and a member of the Committee on Power Plants for Aircraft.

▸ **Capt. Walter S. Diehl, USN (Ret.)** (HF), has been named Chairman of the NACA's newly formed Subcommittee on Aerodynamic Stability and Control. He was formerly Chairman of the Subcommittee on Stability and Control.

▸ **Lloyd R. Everingham** (M), of Cornell Aeronautical Laboratory, Inc., has been appointed to the Technical Advisory Panel for Aeronautics of the Department of Defense. He serves as a consultant on piloted aircraft and guided-missile systems. At Cornell, Mr. Everingham is Director of Tactical Air Operations Research and Development for the Tactical Air Command, USAF.

▸ **Leonard S. Hobbs** (F), Vice-President for Engineering, United Aircraft Corporation, is a new member of the NACA's Industry Consulting Committee.

▸ **Brig. Gen. Charles A. Lindbergh, USAF (Res)** (F), has been appointed by President Eisenhower to the first Board of Visitors of the United States Air Force Academy.

▸ **William Littlewood** (F), Vice-President for Equipment Research, American Airlines, Inc., has been appointed Chairman of the NACA's Industry Consulting Committee. He was formerly Vice-Chairman.

▸ **Clark B. Millikan** (HF), Director of Guggenheim Aeronautical Laboratory at California Institute of Technology, has been named Chairman of the NACA's Subcommittee on High-Speed Aerodynamics. He was formerly Chairman of the Subcommittee on Fluid Mechanics.

▸ **Perry W. Pratt** (F), Chief Engineer at Pratt & Whitney Aircraft Division, United Aircraft Corporation, is a new member of the NACA's Committee on Operating Problems.

▸ **Allen E. Puckett** (AF), Head of the Missile Aerodynamics Department, Research and Development Laboratories, Hughes Aircraft Company, has been appointed to the NACA's new Subcommittee on Automatic Stabilization and Control.

▸ **George H. Scragg** (M), Treasurer of the Early Birds, has been appointed Editor of *Chirp*, the official publication of the pioneer pilots' organization. The size and format of the magazine have been changed, and the editorial office has been moved to 920 East 79th St., Cleveland.

Announcing new appointments to its technical committees for 1956, the National Advisory Committee for Aeronautics named these three engineers of The Glenn L. Martin Company. *Left to right:* Herman Pusin, MIAS, Manager of the Product Design Dept., was appointed to the NACA's Subcommittee on Aircraft Structures; Charles J. Koch, MIAS, Chief of the Aerodynamics Section, to the Subcommittee on High-Speed Aerodynamics; and George S. Trimble, Jr., MIAS, Vice-President for Engineering, to the Committee on Aerodynamics and the Subcommittee on Engine Performance and Operation.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Chauncey F. Bell, Jr. (M), formerly Customer Service Manager and Advanced Design Project Engineer of The Glenn L. Martin Company, has joined the Logistics Department of The RAND Corporation, Santa Monica, Calif.

Major Gen. Victor E. Bertrandias, USAF (Ret.) (AM), has been retained by Pan American World Airways as an advisor on jet operations. A former Vice-President of Douglas Aircraft Company, Inc., General Bertrandias was responsible for flying safety during the Air Force's transition from piston-engine to jet airplanes.

Robert F. Brodsky (M) has joined Convair, A Division of General Dynamics Corporation, as Leader of the Aerodynamics Group at Pomona, Calif. He was formerly Supervisor of the Analytical Aerodynamics Division of Sandia Corporation.

Rudi P. Buschmann (AF) has been transferred from the Burbank, Calif., plant to the Georgia Division of Lockheed Aircraft Corporation as Military Operations Research Division Engineer.

Thomas D. R. Carroll (AF) has been appointed Assistant Design Manager of Bristol Aircraft Limited, Bristol, England. He was formerly Senior Technical Officer (Aircraft) of British Overseas Airways Corporation.

Carl H. Dolan (AF), Consulting Engineer, of Greenwich, Conn., has been elected a Director of Nagler Helicopter Company, Inc.

Cramer W. LaPierre, MIAS, has been elected an Executive Vice-President of General Electric Co. A Vice-President since 1952, he continues in charge of the Electronics, Atomic, and Defense Systems Group, which includes the Aircraft Gas Turbine Div.

Donald W. Finlay (M) has been transferred to the position of Chief of Preliminary Design in the new Transport Division of Boeing Airplane Company.

D. R. Gero (AF), Vice-President of G. M. Giannini & Co., Inc., has been appointed Western Operations Manager. He was formerly Air-Borne Operations Manager.

W. J. Hesse (M) has joined Chance Vought Aircraft, Inc., Dallas, Tex., as Supervisor of the Theoretical Propulsion Group. He was formerly Chief Engineer of the Test Pilot Training Division, Naval Air Test Center, Patuxent River, Md.

Lester M. Hitchcock (M), former Staff Engineer—Structures, has been appointed Chief of Technical Staff, Seattle Division, Boeing Airplane Company.

Temple N. Joyce (AM), President of Bradco, Inc., has been elected a Director of Nagler Helicopter Company, Inc. He also was named Chairman of the Executive Committee.

Eryk Kosko (AF), of A. V. Roe Canada Ltd., has been appointed Scientific Consultant to the Institute of Aerophysics of the University of Toronto. On a part-time basis, he is conducting a lecture and laboratory course in Analysis of Aircraft Structures as part of the fourth-year curriculum in Aeronautical Engineering.

Norman N. Krause (M) has been promoted to Assistant Chief of Experimental Flight by Northrop Aircraft, Inc. He is stationed at Northrop's facility at Edwards AFB, Calif.

Harlowe J. Longfelder (AF), former Staff Engineer—Aerodynamics, has been appointed Chief of Preliminary Design, Seattle Division, Boeing Airplane Company.

Monroe A. Maller (M) has been named Vice-President and General Manager of Avien Service Corporation of California, Culver City, Calif. He was previously European Sales Manager of the Aeronautical Division of Minneapolis-Honeywell Regulator Company.

Frank Mansur (M) has joined Eitel-McCullough, Inc., San Bruno, Calif., as Administrative Assistant to the General Manager. He was formerly Manager of the Government and Commercial Department of Hazeltine Electronics Corporation, Little Neck, N.Y.

Norman F. Parker (M) has been appointed Assistant Chief Engineer of Autonetics, a Division of North American Aviation, Inc. He was formerly Assistant Chief of Autonetics' Guidance Section.

W. A. Patterson (M), President of United Air Lines, Inc., has been elected a Director of The Goodyear Tire & Rubber Company, Inc. He filled a vacancy caused by the death of Ralph S. Damon.

Maynard L. Pennell (M), Chief Project Engineer—Aircraft, Boeing Airplane Company, has been appointed Chief Engineer of the company's newly formed Transport Division.

Vincent G. Polovkas (M) has joined Fairchild Engine and Airplane Corporation as a Project Engineer in the Engineering Development Branch of Fairchild Aircraft Division, St. Augustine, Fla. He was formerly a Senior Structures Engineer with Convair's Fort Worth Division.

John O. Powers (TM) has been named Manager for Aero-Thermodynamics Engineering in the Special Defense Projects Department of General Electric Company. Formerly in G-E's Guided Missiles Department, he was responsible for the aerodynamic design of the Hermes series of missiles.

Walter F. Ring (AM) has joined Industrial Acoustics Company, Inc., New York, as Project Manager. He was formerly with Industrial Sound Control, Inc.

Alfred Ritter (M) has been promoted to Supervisor of the Hydrodynamics, Propulsion, and Structural Research Department of Armour Research Foundation, Illinois Institute of Technology.

Colonel Howard M. McCoy, USAF (Ret.), AFIAS, has joined the Computer Systems Division of The Ramo-Wooldridge Corp., Los Angeles. He is a former Air Force Representative to the Research and Development Board.

Carl Kaplan, FIAS, has joined the Air Force Office of Scientific Research, ARDC, Baltimore, as Director of Aeronautical Sciences. He was formerly Chief of the Theoretical Aerodynamics Division of Langley Aeronautical Laboratory, NACA.

George S. Schairer (F), former Chief of the Technical Staff, has been named Assistant Chief Engineer of the Seattle Division of Boeing Airplane Company.

H. Serbin (M) has joined The RAND Corporation, Santa Monica, Calif., as a Physical Scientist. He was formerly with Convair, A Division of General Dynamics Corporation.

Saul Sokolsky (TM) has joined the Advanced Development Division of Avco Manufacturing Corporation, Stratford, Conn., as an Associate Aerodynamicist in the Applied Research Department. He was formerly a Research Engineer with Curtiss-Wright Corporation, Clifton, N.J.

Edward N. Townsend, Jr. (M), has joined California Eastern Aviation, Inc., as a Vice-President in Washington, D.C. He was formerly Works Manager of Lockheed Aircraft Service at New York International Airport.

Robert L. Wehrli (M) has been named General Manager of the Aeronautical Division of Robertshaw-Fulton Controls Company, Anaheim, Calif. He was formerly Director of Research and Development.

Elmer P. Wheaton (AF) heads the newly established Missiles Engineering Department of Douglas Aircraft Company, Inc., as Chief Missiles Engineer. The company has eight active missile projects.

T. A. Wilson (M), former Assistant to the Chief Engineer, now is Assistant Chief of Technical Staff, Seattle Division, Boeing Airplane Company.

Stanley D. Zemansky (M) has been named Assistant to the General Manager of the Autonetics Division of North American Aviation, Inc. He was formerly General Supervisor—Operations for Electro-Mechanical Products Operations.

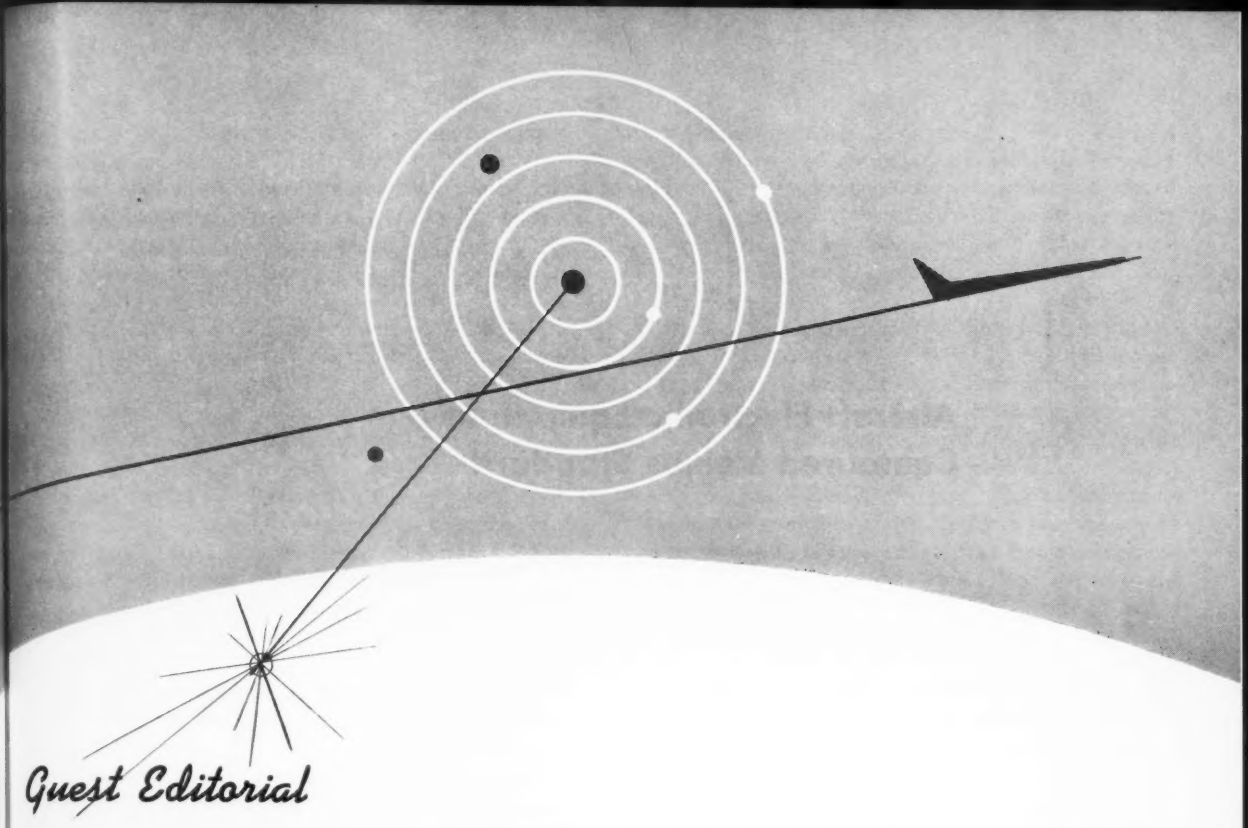
(Continued on page 129)

By

H. Guyford Stever

Chief Scientist

United States Air Force



Guest Editorial

Electronics in Aviation

At this year's annual meeting of the Institute, I heard in the Electronics Session some interesting data presented by Mr. Rempt* concerning the growth and importance of the electronics systems in aircraft with respect to weight, engineering man-hours, and cost. In aircraft which were typical to Mr. Rempt in the period 1940 to 1955, the electronic system had grown in weight from $2^1/_2$ to more than 10 per cent, in engineering man-hours from $11^1/_2$ to 38 per cent, and in cost from 16 to more than 48 per cent. Though you and I might have picked somewhat different aircraft as typical, any such statistics as these are more than enough to prove the importance of "Electronics in Aviation" today. To one who entered the field of aviation through electronics, these are pleasant-sounding statistics. Still, they make me pause to think over the vital question of whether or not we are getting our money's worth in improved performance capabilities in the aircraft which use such large amounts of electronics.

What are some of the functions of the electronics which we build into today's aircraft? I think the most spectacular is that furnished by radar and infrared in the provision of the capability of seeing aircraft and ground objects at great ranges in good weather and bad, in daylight and darkness. There are other functions of import as well. Electronic computers perform calculations which are beyond the capability of humans because of the combined requirements of speed and complexity. Electronic components are combined with the classical sensing devices such as gyros, accelerometers, and pressure and temperature pickups to measure more accurately the position and complicated motions of the aircraft. Electronic devices are teamed with electrical, electromechanical, or pneumatic servomechanisms to give the pilot a stronger and, at the same time, a lighter touch, one with the proper frequency response and one that can be monitored to prevent destructive overcontrol. The proper admixture of all these in the right aircraft can result in an interceptor in which the entire interception phase can be carried out automatically or in a bomber in which the terminal bombing run can be made automatic. It is well known that these objectives have been pursued actively by the Air Force for almost a decade. Already some of our operational interceptor and bombardment missiles carry out this type of automatic operation.

Whenever I sit in a U.S. Air Force fighting aircraft—be it a long-range bomber or an all-weather interceptor—among all the switches, dials, knobs, meters, handles, lights, and cathode-ray scopes which are in some way connected with the electronic and other

(*Continued on page 126*)

* Rempt, Henry, and Cronin, M. J., *The Impact of Electronic Equipment on Electric Generator Design and Aircraft Power Plants*, appears in full in this issue on p. 87.

A presentation is given of the pros and cons of using these two forms of electronic apparatus in relation to available aircraft space, mission requirements, cost, and reliability of proved designs; and a compromise between them is suggested.

Aircraft Electronic Equipment—Contoured Versus Standard

R. J. Henderson* and G. P. Allison*
The Glenn L. Martin Company

EVERYONE KNOWS that, in modern high-performance aircraft, the complement of necessary electronic equipment is constantly increasing. Concurrently, the cross sections of these airplanes are changing so that they provide smaller and less convenient spaces for electronic gear.

All of this equipment exists in standard form or is being developed into standard forms that may not readily fit the available space. If the designer who integrates electronics into the aircraft specifies that the gear be contoured to the available space, he soon discovers that the cost of redesigning it is many times greater than that of designing a new and special landing gear or wing. The space saved by redesign may not be justified for the number of aircraft to be constructed.

The system designer, then, must decide whether it is better to jeopardize the program's budget and schedule by repackaging the electronic equipment or to jeopardize the performance of the aircraft by eliminating some of the electronic equipment or by changing the shape of the aircraft. This is a very difficult decision for the design engineer to make. Neither course will solve his problem, so his decision is rather a choice between two evils.

How have the electronics industry and the air-frame industry forced this unhappy decision on the aircraft system designer?

To examine the aircraft design problem, it should be noted that an aircraft is generally designed around the engine; all portions of the aircraft are designed with this in mind.

The modern engine is capable of very high speeds if combined with a long, narrow, pointed fuselage. In fact, the designs are tending to become still narrower and thinner. So, then, we can predict the form of aircraft to be produced in the next 10 years, and we know that the space available for the installation of electronics gear will be smaller and less accessible and that it will probably have at least one curved surface as a boundary. We freely predict that no aircraft designer can make his high performance aircraft "fat" in just the right places to accommodate electronics gear—however necessary—because no impairment of aerodynamic performance will be permitted.

Meanwhile, the electronics industry has been following its own independent course improving its techniques and equipment. Today's missions are complex and demand much equipment. To illustrate: a number of years ago an airplane was considered to be well equipped if it had a radio for communication and a direction finder, but now the aircraft must have several radars for search, altitude determination, and navigation. It probably needs equipment to identify itself, communication receivers and transmitters covering many channels, electronics armament control systems, landing aids, direction finding equipment, autopilot, intercom set, and even recording equipment. Each aircraft requires additional gear, such as bombing systems, to accomplish its mission. Moreover, since the modern airplane is less stable and since the pilot's permissible reaction time is much less, many pilot functions have been taken over by new electronic gear.

During this development period, consideration of size has been subordinated to equipment performance characteristics—even though transistors, printed circuits, and other techniques helped in miniaturization. The smaller equipments are, nonetheless, still being put into the standard forms for packaging electronic equipment. These sizes and shapes have resulted from years of successful experience and from mutual agreement between industry and government agencies. Nearly all specifications for new equipment require that it be designed to these standards. For this reason and to achieve the other benefits of standardization, the designer does design to them.

At the present time, these two independent lines of development—aircraft and electronics—have diverged

Presented at the Electronics Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Electronics Department.

so much that steps must be taken to get them back together.

Contouring, on the other hand, has much to recommend it. In one of The Glenn L. Martin Company's recent proposals, the designers selected a piece of electronic equipment that is presently being built in a trunk-shaped rack, but they found it necessary to take the individual chassis out of the trunk and put it into a special compartment which more nearly fitted the available space.

This means of reassembling equipment into built-in compartments is a step in the correct direction, but it cannot be carried far enough with present standard equipment to make it possible to utilize all of the available space. The aircraft system design engineers of several recent aircraft have chosen to have all of the electronic equipment packaged or repackaged into tailored shapes since they considered this to be the only means by which they could carry the necessary electronic gear.

Fortunately, the great majority of the individual electronics components such as resistors, condensers, and transistors are small, and they can be repackaged into almost any nook or cranny without harming their performance. There is certainly precedent for designing the electronic equipment to the contour of the aircraft since it follows the same engineering principle that calls for the design of a new landing gear and a new wing to provide the optimum performance for a given aircraft. At the present time, following this principle requires that every electronic system be repackaged for each new aircraft in which it is to be used because the internal arrangement, the total electronic complement, and the dimensions of the fuselage of all aircraft are not identical.

If the customer is going to use a large number of these aircraft, the electronic equipments will be used in such quantities that the unit cost of redesign will become relatively small.

Since we are also concerned about losing advantages we have derived from standardization, it is time to examine the reasons for and the advantages of standard packaging.

The repackaging process is essentially the reduction of a complex piece of operating equipment to a pile of component parts and a schematic drawing. Next, these parts must be reassembled to fit the available space and redesigned wherever necessary so that the new assembly performs as well as the original—although this last goal cannot always be accomplished. This means the entire wiring and cabling layout must be redone, new radiation interference problems must be overcome, and unplanned coupling and parasitics must be eliminated. This type of program uses many man-hours and may easily become a major portion of the system design effort.

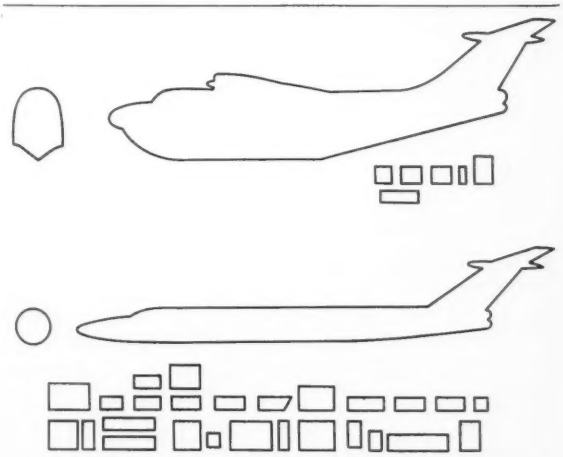
Use of standard case and rack sizes and shapes improves reliability because the designer can use a large percentage of designs which have already been proved satisfactory and reliable. If the designer redesigns to a new shape, much of this advantage is lost. The best way to achieve orderly improvement of performance and reliability is to change as small a portion of a proved design as is practical. Experience with a proved design has been shown to be of more value in obtaining reliability than elaborate calculations of a totally new design.

Increased engineering expense and possible impairment of performance are not the only penalties for departure from standardization. The maintenance technicians who have become familiar with the equipment in its original form must go through a learning period during which their efficiency is reduced. A project RAND report, dated December 3, 1952, emphasizes the importance of this point. It states that the cost of the maintenance of any piece of electronic equipment during its life may be eight to ten times the cost of the equipment itself.

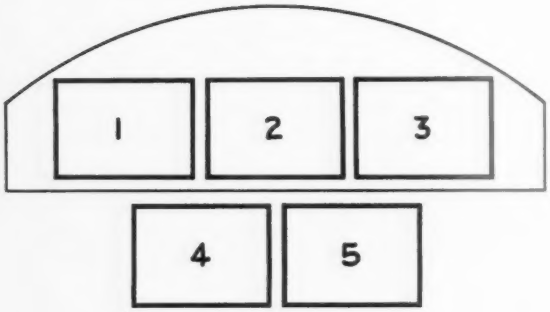
The customer also derives a great benefit from standardization. Standard gear reduces the cost of cataloging, stocking, spares supply, and maintenance. If a radio transceiver can be used interchangeably for three different types of aircraft, the total cost is little more than a third of what it would be if a different version had to be carried for each ship. Replacements and repair parts can be stocked at smaller depots because the parts are more commonly used, and maintenance can be accomplished with less loss of time for the aircraft.

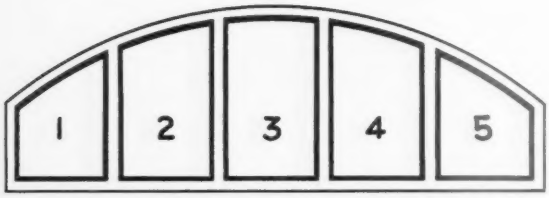
It is apparent that the designer with a true system effectiveness concept must retain as high a percentage of standard electronic equipments as possible.

In review, the aircraft system design engineer has a list of the mission functions and knows the communication and protection requirements. With this information, he can determine the required electronic equipment. A sum of the sizes of the required standard equipment and an estimate of the new equipment required for this mission can be obtained. He also knows

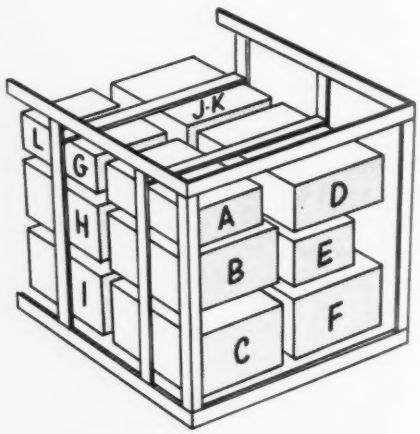


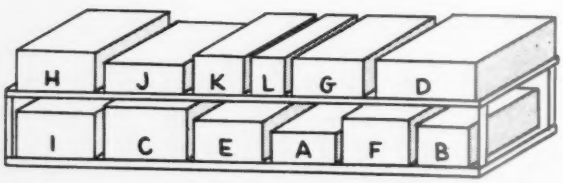
As available space for electronic equipment diminishes, the quantity of it in aircraft increases. At the top of this figure is a 1950 seaplane and its complement of electronic gear. The lower drawing represents an airplane of roughly 1958 vintage and its black boxes.



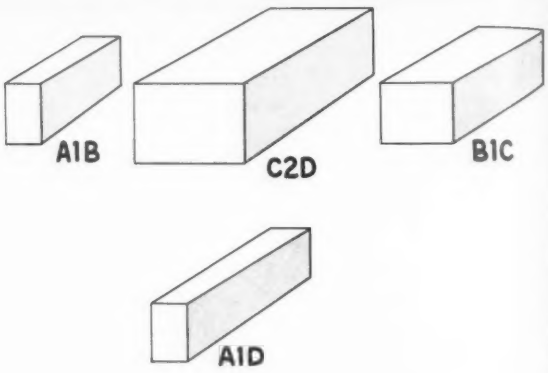


Careful planning of equipment case shapes makes possible more efficient space utilization.



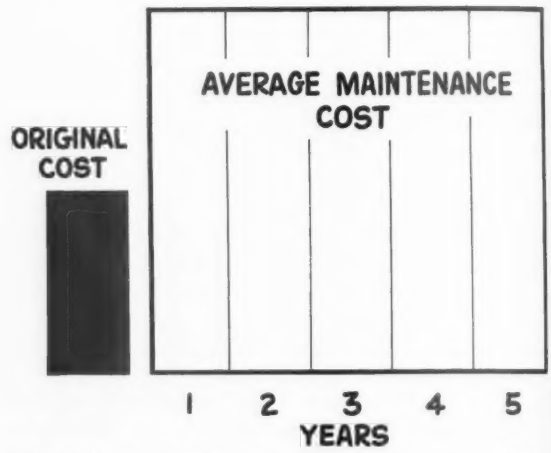


If the outer containers are discarded and the chassis are rearranged, equipment can often be fitted into the slender shapes of modern aircraft.

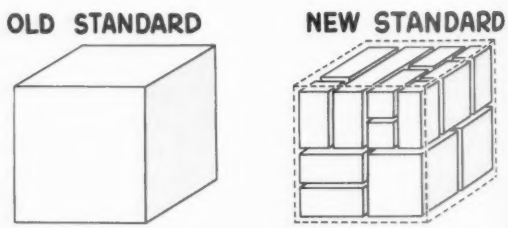


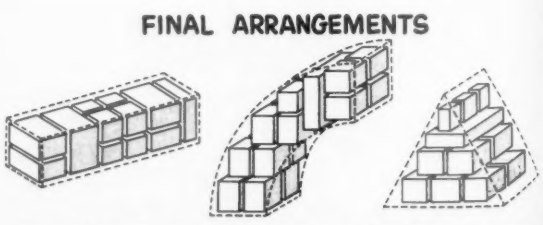
MIL-C-172-B

At present, military specifications for electronic case sizes and shapes are not consonant with efficient utilization of aircraft spaces.



The high ratio of maintenance-to-manufacturing costs emphasizes the desirability of engineering efficient maintenance into each design.





Extremely small circuit components lend themselves to a variety of final shapes.

the approximate volume and dimensions that can be allocated to this equipment. Invariably, the size of the desired electronic equipment is greater than the available space.

In examining his problem, he finds that the desired equipment falls into four categories:

(1) Some equipment, having new requirements, must be developed for his aircraft, and he will have control over its size and shape. Therefore, it can be suitably contoured; however, if this is done, it may be impossible to use this equipment on any other aircraft without repackaging it.

(2) Sometimes a significant space saving (and other advantages) can be achieved by combining two or more equipments. The designer will be able to exert some control over the size and shape of the combined equipment.

(3) Some of the desirable functions just must be cut out, and there is no question about it. So, they are cut out. However, the system design engineer must not omit any equipment which would impair the basic mission.

(4) This category of equipment must all be put into the aircraft. It would be most impractical to make a bomber which should be an all-weather weapon into something which could fly only under good visual flight conditions. The designer cannot eliminate something like an instrument landing approach system. Here he cannot avoid the old question: Is it less harmful to use standard equipment and require a bigger aircraft (with the attendant increase of weight and greater fuel requirements), or is it less harmful to specify that the equipment be redesigned? It should be noted that the customer is paying for any redesign, and his approval of the action must be obtained.

It has been established that the individual electronic components are small and lend themselves to rearrangement. It has been shown that standard packaging configurations provide many benefits in economy and reliability not only during the design phase but also after delivery to the end user. To retain most of these benefits and, at the same time, provide some flexibility in the shape of the finished equipment, standardizing on very small units should be investigated. In the present packaging scheme, a separate chassis is usually a complete entity in itself. It has its own mounting base, shock mounts, protective cover, individual power supply, and often a ventilating fan. Suppose that we standardized, instead, on single, compact, easily replaceable units which, at present, might be considered subassemblies. These units, using a few standardized voltages, cooling methods, and attachment methods, could be standardized in a few carefully planned sizes and shapes. They should contain a single, logical element of the overall design and should include only those components which must be oriented with each other to control such things as couplings and radiation losses. These units might be as small as one tube with its associated components. Circuit considerations will require the grouping of more components in some cases.

A number of companies have been working with, or producing, equipment containing small, easily replaceable units known as modular construction, plug-in subassemblies, or unitized design. Some of the companies that have been doing this type of work are Collins Radio Company; Bendix Eclipse-Pioneer Division, Bendix Aviation Corporation; Hoffman Electronics Corporation; Federal Telephone and Radio Company, Division of International Telephone and Telegraph Corporation; General Electric Company; and Stromberg-Carlson Company. It is our belief that these companies have adopted such a form for easier production of high-density electronics equipment for easier maintenance and for flexibility of function. Our reason for suggesting this type of construction is for flexibility of shape of the final box or container.

In this plan, the design of a new prototype equipment would be completed when these new, small, standard units had been properly developed, assembled in a simple, easily set-up form, and tested. The original design would no longer require that chassis cases, shock mountings, intercabling, cooling, and power supply be developed. This portion of the design would be accomplished for each specific aircraft to permit the best use of available space. At the same time, the standard units would be retained intact without modification. The space problem of the aircraft designer would be somewhat relieved; a great deal of the original design would be retained intact; and spares and maintenance would be prevented from becoming a complete bedlam of similar, yet different, equipments.

We are suggesting a means whereby the aircraft system designer will be permitted to achieve additional economies in space since he would be required to engineer the cases, the common power supply, and the common equipment cooling system which would operate under his specific environmental conditions.

Recommendations of the ideal configuration of these new standards is beyond the scope of this paper. However, it is recommended that the experience of industry with these easily replaceable subassemblies be collected, analyzed, and used by some suitable standardization authority in setting up new standards for electronics equipment, which will permit using space as it exists.

The modification of the mechanistic design of the servocontrol system in the light of human pilot characteristics.

Integrated Flight Equipment System with Primary Emphasis on Instrumentation and Controls

C. F. Fragola* and M. A. Sant Angelo†
Sperry Gyroscope Company, Division of Sperry Rand Corporation

Introduction

Present progressive aircraft equipment design calls for consideration of the total integrated pilot-equipment-mission requirements. The stringent demands of modern-day aircraft have imposed increasingly higher performance requirements on each component and on the total pilot-aircraft-equipment control system.

The development and design of the optimum total control system from a mechanistic point of view is similar to that of a basic servo and requires:

(1) Analysis and evaluation of the overall mission.

(2) Analysis and evaluation of the assumed fixed components such as the man and the aircraft.

(3) Analysis and evaluation of external disturbances.

(4) Development and design of the optimum control and feedbacks to stabilize the man-machine system and to assure mission success.

The inclusion of the human pilot makes it necessary to modify the mechanistic design to accommodate his physiological and psychological characteristics. The solution demands that the proper proportioning of the mission duties between the man and the machine be established by evaluating the distinct characteristics of each. The overall effectiveness of the integrated combination must be measured against the overall mission requirements.

The solution of this multifarious problem has been described as equivalent to the slaying of Hydra by Hercules—i.e., the problem cannot be overcome by any single effort. However, here and there have developed some minor "breakthroughs" which are tending to establish some order in this intricate maze, converting it slowly into a more clearly crystallized problem. The solution is evasive because no one specialized scientific skill has developed tools that are completely adequate. Evidence to date indicates that at least the pilot, the operations man, the psychologist, the engineer, and the mathematician have to combine talents. In the engineering and mathematical fields, with which the authors are somewhat familiar, servoanalysis is powerful. There is evidence, however, that to incorporate the human pilot effectively, it may be necessary to explore at least the associated fields of information, game, and probability theories. In the dynamic field of aircraft design, no phase can lag behind for long. It is necessary that the terms of the man-machine problem, which looms so large, be reduced to a point where familiar equations on analogies will attract the interest of more practitioners and enable them to apply their talents toward a solution, converting this from art to science.

The "state of the art" and the limitations imposed on the length of this paper permit nothing more than a quick dash through the field of integrated flight equipment systems, focusing here and there on an aspect that has been of particular interest to the authors. This will result in primary emphasis on instrumentation and controls, not because these are the all important focal points, but simply because the authors are more familiar with this field.

General Discussion

There seems to be evidence that the present cockpit has been permitted to grow like "Topsy" into a maze of multiplicity, and, as such, it is doubtful that systems have been optimized to provide the maximum in performance and safety or, in operational terms, the maximum service per dollar expended. As an example, when a system is being optimized from the overall mission point of view, it is found that one no longer restricts reliability considerations to whether one or two radios, or two flight instruments, are required. More consideration is given to the type and relative importance of basic information and data required for the particular phase of the mission and to ways and means

Presented at the Aircraft Design Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Department Head, Instrument Systems, Aeronautical Equipment Division.

† Senior Engineer, Aeronautical Equipment Division.

for providing the equivalent information from varied sources. Usually the reliability of duplicate information is enhanced if it is obtained through a distinctly different means—that is, through redundancy.

To arrive at a scientifically optimized aircraft for a specified mission, a complete operational analysis is required. From the flight control standpoint, this must include the establishment of a philosophy of cockpit organization which will best allow the human pilot to function as a manager. As a manager, he must have an organization in which the operational elements are so organized (duplication and redundancy) that, when any element or combination thereof deteriorates, he is immediately informed (monitor) of this condition and can employ means (stand-by) to supplement the function. This requires far more than merely increased automation and duplication.

To get a feeling for some of the contributing factors to be considered in arriving at an optimum system, consider the simplified mission of a commercial air liner required to make a standard schedule flight. First, the *mission objectives* must be defined. From this a *general flight plan* is evolved which is broken down into *mission phases* for detailed consideration, leading to the evolution of the detailed operational control requirements. Here the mission objectives have been generated principally by passenger travel requirements and air-line desire to provide a service at a profit. The general flight plan involves considerations of the existing situation; judgment based on pilot experience; aircraft performance data; and general route data such as average terrain, schedule, expected weather, applicable CAA and air-line regulations, etc., as illustrated in Fig. 1. The mission phases include take-off, climb to altitude, en route flight, approach, and landing. The process is complicated because considerations for each of these three steps are interrelated. Each of these steps are equally important, but it is the intent of this paper to focus primarily on the control aspects of the problem, found generally in step three.

A brief review of the historical evolution will provide an insight and aid in understanding the interrelated problems of aircraft flight control and cockpit management, which is centered about a control element

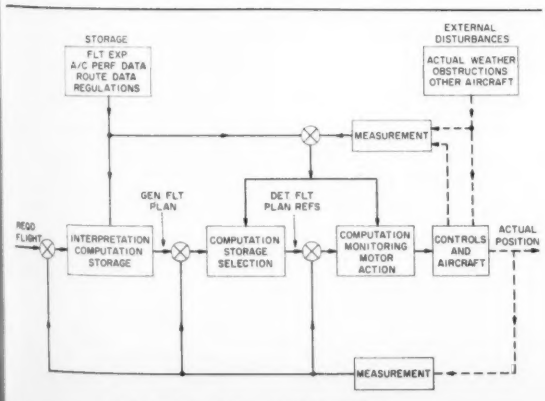


FIG. 1 GENERAL OVERALL CONTROL SYSTEM SIGNAL FLOW BLOCK DRAWING

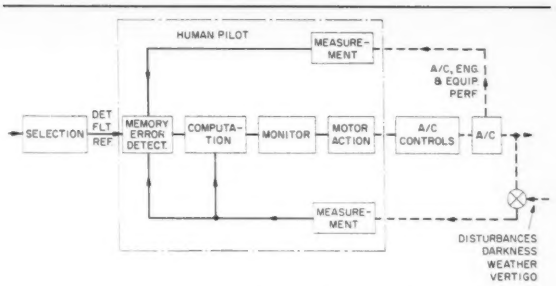


FIG. 2 BASIC PILOT-AIRCRAFT SERVO CONTROL SYSTEM -CONTACT FLIGHT-

with the most complex and versatile features (transfer characteristics, in servo language)—the human pilot.

For the purpose of illustrating the functional growth of aircraft controls, consider first early contact flying without any instruments whatsoever in the cockpit so that the human pilot had to provide all the measurements, control decisions, and control motor actions required. The scheme of this operation is illustrated in the block diagram of Fig. 2, which shows that the overall control process forms a control loop that includes the pilot in both the forward and feedback loops. For the control of aircraft, the human pilot requires that two basic conditions be fulfilled: He must know the control movement necessary, and he must have sufficient confidence that the control information is correct.

For contact flight with the slow aircraft of the past, these requirements presented few problems because the pilot had little difficulty in knowing qualitatively at least what control was required. He had great confidence in this information because it rarely failed him. Further, the imminence of the failure could usually be detected in sufficient time to avoid disaster, as during the gradual development of a fog.

The control process in contact flight consisted of appraising the situation of the aircraft, comparing it with the pilot's intended plan of flight, determining the error, and making a control movement—thus moving the plane, thereby changing the error, which the pilot further perceived, etc., as a "feedback" on his initial control. This continuous, error-correcting, closed-loop system permitted the pilot to achieve adequate control of the aircraft in spite of the fact that his initial control motion was not a perfect one. The feedback process provided the "self-correcting" characteristics which were necessary. If, for example, this process had been an "open-loop" system, in effect, the pilot would have had only one chance to put in the correct control initially, as is the case of firing a rifle. Open loop is essentially a one-shot control.

In the case of flight, this situation could be illustrated by the pilot of a noninstrumented aircraft entering a cloud bank. If the last control were perfect and if the aircraft encountered no internal or external disturbance (which would be extremely unlikely), he could hope to come out stable and upright; otherwise he would be in trouble.

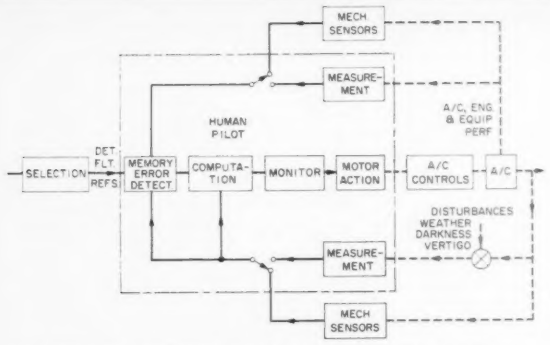


FIG 3 BASIC PILOT-INSTRUMENTS-AIRCRAFT SERVO CONTROL SYSTEM -INSTRUMENT FLIGHT-

Because aircraft are flown in a dynamically disturbed environment (the disturbances can be both internal and external), only a closed-loop control system will succeed in maintaining control. Therefore, in contact flight, whenever this loop degenerated toward an open loop—as when either darkness or weather occluded the pilot's view or when false information was inserted into the feedback loop because of the pilot's measurement inaccuracy and vertigo effects (pilot's loss of sense of balance)—the control degenerated and ultimately failed. The use of instruments to supplement the pilot's measurements was the first significant aid in avoiding control degeneration. Fig. 3 illustrates the servoloop system resulting when measuring devices, such as air-speed indicators and altimeters, are used in addition to the pilot-sampled physical measurements. Both parallel feedback paths may be used. This provides a degree of redundancy since the pilot can read altitude from his altimeter or visually check it. The instrumentation provides three significant improvements over contact flight without instruments:

(1) A feedback signal keeps the loop closed in spite of such external disturbances as weather or darkness.

(2) The feedback signals are accurate, and, as mission needs require, accuracy can be increased.

(3) Simple mechanical additions provide memory devices which relieve the pilot of the necessity of remembering the nominal reference and of measuring his performance against it.

While adequate, the early instruments were influenced adversely by a variety of environmental factors, such as temperature, pressure, and acceleration. It was also found that, while they adequately overcame the pilot's vertigo, the solution was not absolute.

Fig. 4 is a block diagram showing a portion of the servoloop and, in particular, the feedback sensors and external system disturbances upon them. From the early instruments and still for some time to come, instruments will continue to improve so that the information they provide to the feedback paths will be more accurate. Concurrently, there have been strivings to eliminate the last vestiges of vertigo for the pilot. It will be observed that these were mainly improvements in the feedback loops—little improvement was provided for the forward loop. In fact, because of increasing demands on the forward loop imposed by more unstable aircraft and the need for lower minimums in bad weather approaches, the forward loop was actually becoming increasingly inadequate.

As noted, an instrumentation system for aircraft instrument flight must give continuous information describing the condition of the aircraft to achieve the functional control requirement. In addition, since the instrumentation can fail, the pilot demands increased assurance that his information be correct. To get this assurance, the pilot must be convinced that the complete overall pilot-control system is extremely reliable. This reliability can be established if perfect components could be provided. Any imperfection requires that alternate means be provided to bridge the gap. This suggests, in broad form, a comprehensive system which provides characteristics of adequate checks and balances. To provide these features, the system must inform the pilot when some element is malfunctioning—it needs *monitoring features*. In addition, the system must provide alternate means of control—*stand-by features*. These features can be provided in the form of duplication or redundancy and should be skillfully organized within the confines of a definite framework of cockpit management philosophy.

If the "assurance" instrument simply provides an indication that the primary information is in error (and nothing more), then this instrument is defined as a "monitor." If, in addition to an error indication, it provides a means of achieving adequate flight control it is a "stand-by" instrument. For increased mission success assurance, a *monitor is not sufficient—a stand-by is required*. However, monitors do serve to indicate to the pilot when the stand-by control is required. In short, the monitor is the "red light" telling that there is trouble, whereas the stand-by is the reserve mode of control. Unless related to the mission or mission phase objectives, it is not possible to establish whether a control system is either a monitor or a stand-by. A stand-by for a mission phase may well become simply a monitor for the major overall mission.

As aircraft grew larger and flew faster and farther they became more complex, and better performance was

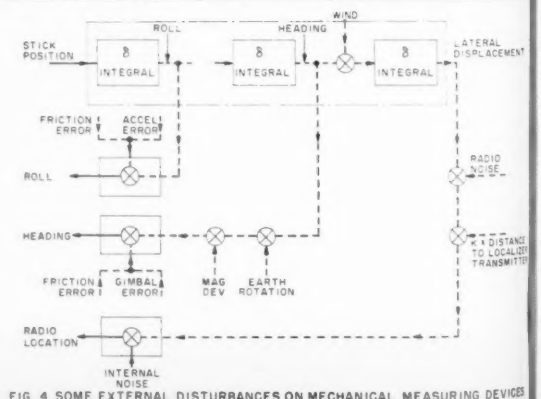


FIG 4 SOME EXTERNAL DISTURBANCES ON MECHANICAL MEASURING DEVICES SIGNAL FLOW BLOCK DRAWING - ROLL CHANNEL AXIS

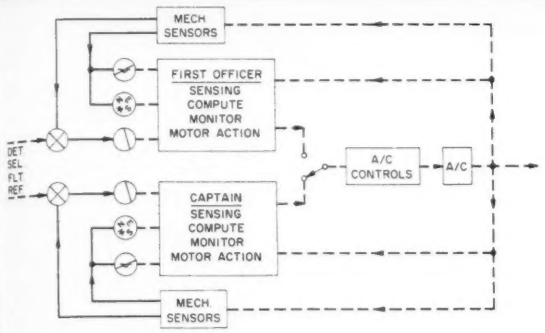


FIG 5 DUAL INSTALLATION
BASIC PILOT-INSTRUMENTS-AIRCRAFT SERVO CONTROL
-INSTRUMENT FLIGHT-

required of the control loop including the pilot, aircraft, and controls. Safety of flight became the main focus. To achieve the maximum in reliability and safety, the aircraft industry has followed the principles of duplication, reserve systems, and redundant systems. Therefore, from single pilots and engines evolved the dual-piloted, multiengined aircraft; multiple power supplies; multiple flight, navigation, and approach instruments; multiple radios, etc. Fig. 5 illustrates in simplified block form the general signal flow in a dual system. For simplicity, the detailed signal flow after each human unit is omitted.

For the sake of clarity, it is necessary to define duplication and redundancy more precisely. Duplication will be retained for those types of information or control which exist in duplicate in either an identical or at least explicitly equivalent form—i.e., providing a "horizontal" type of repetition. Redundancy will define the form of duplication which is other than directly or identically equivalent. These definitions provide a means of classifying in an enlightening manner the various forms of duplication so that their contribution to the mission objectives may be more adequately evaluated.

Duplication, or the horizontal dimension, will cover such cases as multiple engines, multiple pilots, multiple identical flight instruments, etc. (*duplication in kind*). Redundancy is viewed as a vertical dimension giving a *duplication* in variations of *degree*. These two coordinates suggest a matrix which maps the field of all possible combinations of systems that may be used. It is hoped that this matrix will eventually be refined to mathematical terms to provide an orderly and more exact science for optimizing a flight system for a particular mission.

Duplication provides a ready and explicit comparison between two or more elements. However, since the same element is repeated, there is the possibility that a common environmental factor or a common reading error can make all elements fail at the same time. In a redundance comparison, the implicit nature of the information makes direct comparison more difficult, if not impossible. For instance, a heading change can be determined by reference to a heading indicator or by timing a turn using a rate-of-turn indicator. While the same information is obtained, at no point is a direct numerical comparison possible. However, since the information compared is from somewhat different sources, there is less probability that some one environmental factor will cause both sources to fail either simultaneously or in the same manner. An example of this is the use of ILS and GCA together for instrument landing approaches where the information transmission means is different and distinctly independent.

The concepts of duplication and redundancy are manifested also in clockput management philosophy in the form of "split" (duplication) and "common" (redundant) cockpit systems. The concepts of split and common cockpits are illustrated in the simplified block schematic of one possible arrangement as shown in Fig. 6. For a completely split cockpit, the pilot and copilot have completely independent instruments, and each person independently sets in any program changes required. Then assuming the pilot is in command, he flies the ship, making all the control actions and decisions, while the copilot, from his knowledge of the flight plan, checks his instruments. Since the pilot's and copilot's instruments are independent, a high degree of instrument reliability is achieved with some confusion possible when the instruments disagree. The copilot also checks the pilot's performance relative to the general flight plan. However, it is not always feasible to allow both to achieve this independent setting of plan because of pressure of other duties.

The common cockpit arrangement provides only one program changer for both sets of instruments. It is usually recommended that this program changer be located centrally between the pilot and copilot—perhaps on the glare shield. The objective here is that there should be only one plan, and the particular physical location of this unit will provide an automatic signal to the copilot when the pilot reaches up to make a change of plan (or vice versa). Advocates of the common cockpit recommend that all the instruments on both sides of the panel be operated from a common source—i.e., one radio receiver, one gyro, etc. With this arrangement, the copilot concentrates on checking the performance of the pilot. This, it is believed, he does better because of the relief from the need to set his

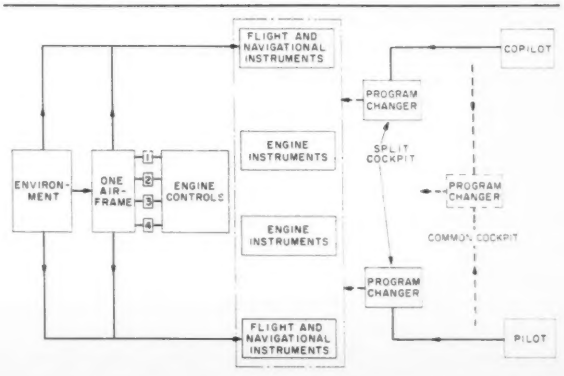


FIG. 6 SIMPLIFIED DIAGRAM OF "SPLIT" AND "COMMON" COCKPITS CONCEPT

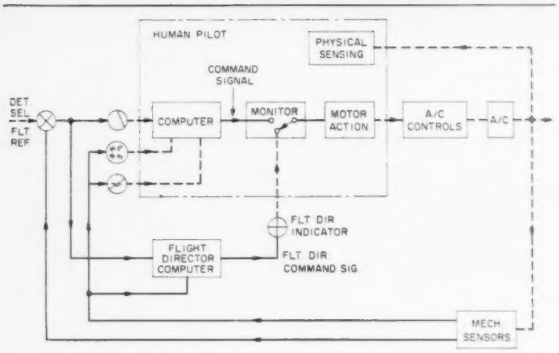


FIG. 7 BASIC PILOT–INSTRUMENTS AND FLIGHT DIRECTOR AIRCRAFT SERVO CONTROL SYSTEM

own plan and his intimate knowledge of the sequence of plan changes. Reserve sources are provided, but they are brought into use only when switched at the program changer to replace the original set.

It is doubtful that the extremes of either split or common cockpit are ever used, but the possibility of the two extreme philosophies stimulates speculation of the broad area in between. The reason the common cockpit is at all practical is that there is a redundance in the cockpit which advises when it is necessary to switch to the other receiver or gyro.

Dual pilots reinforce both the forward and feedback loops and provide relief for the longer flying times involved. The control task, even with a pilot and co-pilot, requires methods to alleviate the situation. In general, a pilot is faced with the problem of measuring, interpreting, computing, and then performing a control or motor action. This is a continuous, rapid sequence process which a pilot must go through prior to each deliberate aircraft movement. While a copilot can take care of ancillary controls, give advice or warning, or substitute for the pilot, the actual aircraft control loop can only include one pilot at a time who must—as a minimum—measure, interpret, compute, and act. Initially, instrumentation took care of the measurement task. Next the automatic pilot took over the motor action. From a simple individual axis damper system, the automatic pilot has continuously progressed to perform more effectively the motor control at the human pilot's command. The addition of computing facilities to the automatic pilot permitted this device to take over a wide range of aircraft control. In fact, under certain conditions, current automatic pilots completely handle the control problem of measurement, interpretation, computation, and motor action and do it far better than the human pilot can. They thus provided more relief for the human pilot and greatly improved the control performance in terms of accuracy, tightness of control, and speed of response. With these modern automatic pilots, the functional problem of flight control has essentially been solved. However, unlike an unmanned guided missile, the air liner carries a human pilot and cargo which are all vitally concerned with absolute safety. In spite of the high degree of reliability provided by these equipments, it is still appreciated that any man-made device can fail.

As the flight control problem became more complex, it increasingly emphasized the requirement for management skill in addition to manual dexterity on the part of the pilot. To serve in this increasingly important executive role, the pilot needed monitoring and reserve means. For aircraft of the recent past, the pilot did have this reserve with his normal complement of flight instruments. The need for reliable instrument landings with low weather ceilings and the higher frequency flight control response required for the present and future high-performance aircraft demanded a more comprehensive reserve. With the normal flight instruments, the degree of precision, reliability, endurance, and frequency response of the control loop—including the human pilot—was becoming inadequate. The flight instruments provided discrete bits of information, such as attitude, heading, altitude, radio beam signals, etc., which the pilot had to scan, interpret, and compute before he could perform a proper control movement. The time delay for this process limited the maximum speed of response of his control loop.

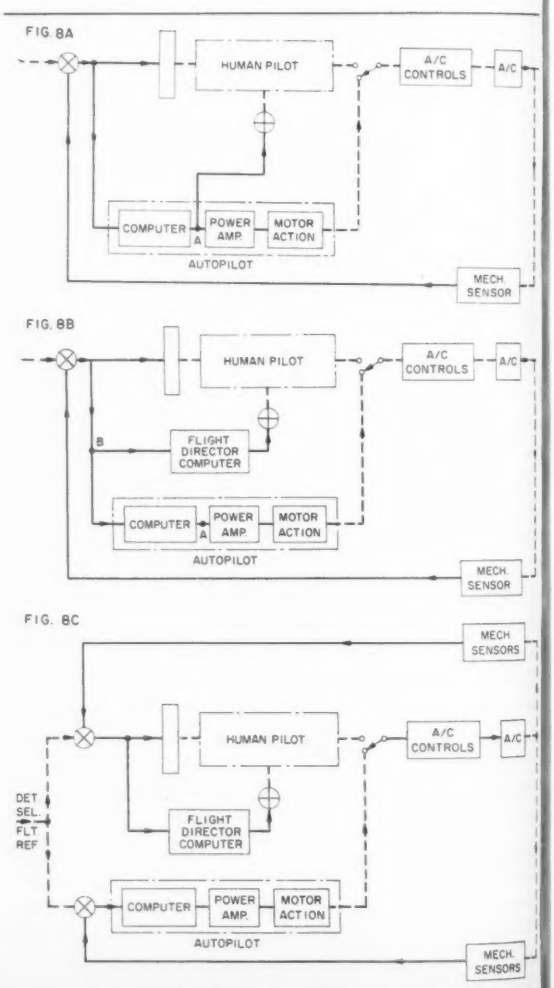


FIG. 8 PROGRESSION OF FLIGHT DIRECTOR SYSTEM FROM PARTIAL TO COMPLETE STANDBY

MODEL C-6
GYROSYN* COMPASS INDICATOR

MODEL HZ-1
HORIZON FLIGHT DIRECTOR

MODEL R-1
PICTORIAL DEVIATION INDICATOR
ON ILS

FIG. 9. Sperry Integrated Instrument System.

To increase the speed of response, improve the precision, and provide more pilot endurance and reliability, the flight director concept—which provided a new dimension in aircraft instrumentation—was evolved. The Zero Reader* flight director, the first of this type, was introduced by Sperry. The changes to the pilot's control loop are indicated in Fig. 7. The diagram shows that scanning, interpretation, and computation are eliminated as pilot burdens. This is achieved in the flight director computer which presents to the pilot simple direct attitude control demands on a crossed-pointer indicator, directing the pilot, instant for instant, whether to roll right or left or pitch up or down, and how much for how long. Controlwise, the flight director increased the frequency response of the pilot control loop; therefore, he had stand-by means of control for the modern automatic pilot.

With these new tools—the modern comprehensive automatic pilot and flight directors (flight instrumentation with a new dimension)—it is advisable to restudy the problems of aircraft flight control and cockpit management to evolve improved concepts which will exploit the new features. The terms "monitor" and "stand-by" are not absolute but can be applied only when the relationship to the hierarchy of mission levels or phases is established. For instance, a standard flight instrument panel for most flight mission phases serves as an adequate monitor and stand-by for the automatic pilot. However, these instruments are not adequate stand-bys for the combination of automatic pilot and beam coupler because a mission phase of the combination may include a landing phase with a 100-ft. weather ceiling. Since the standard instrument panel does not provide adequate instrumentation for the pilot to make landings reliably under these conditions, they serve in this case only as a monitoring, rather than a stand-by, function. If, however, an adequate flight director is included in the flight panel, this more comprehensive panel becomes a stand-by because, with this, the pilot and his instrument system can reliably make the approach in the case of automatic control failure.

A maximum in control stature, reliability, and confidence assurance is achieved when a flight director system becomes a complete stand-by and complete monitor for the entire automatic pilot-sensor system. This has been noted by some air lines and is in actual practice in dual instrumentation aircraft insofar as it is possible with present-day sensors. True, it is possible to use one computer to control both the automatic pilot and the flight director indicator simultaneously, but a compromise in reliability, stand-by use, and confidence assurance must result. Figs. 8A—8C illustrate in simplified form the progression from partial to complete stand-by for a flight director system depending on its loop form. Note that a flight director system which receives information at point A is a stand-by for only the power and motor action portions of the automatic pilot. It is of no assistance in monitoring the computer or signal sources. An increase in intelligence level control is achieved when information is obtained from point B, in which case it is a stand-by in addition for the computer section. Fig. 8C illustrates the case where it is also a stand-by for the sensors. Since the human pilot becomes an integral part of the flight director control loop, he can determine what to ignore and what to control. This permits a simplified form of computer which need not have special provisions to eliminate hard-over signals, switching transients, certain forms of noise, and engage-disengage disturbances.

Even with a flight director and automatic pilot, the requirement of extreme reliability which is necessary for pilot confidence is not met completely. In addition, it is necessary to make sampled qualitative computations by means of the standard flight instruments for monitoring purposes. Should this indicate malfunction in both the automatic pilot and flight director, quantitative computations (stand-by) are then necessary for proper flight control. Thus, it is necessary

* Reg. U.S. Trade Mark.

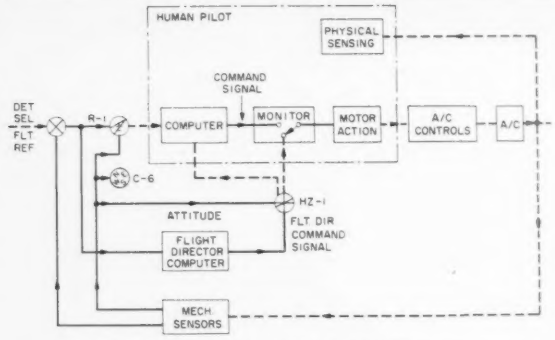


FIG 10 BASIC FLIGHT CONTROL SERVO SYSTEM
-IMPROVED MONITOR-STANDBY INSTRUMENTATION-

to go back and examine the basic instruments, redetermine their role, and design them specifically to perform the required functions of monitor and stand-by for pilot assurance and reserve control. Providing for pilot assurance is a vital necessity for a successfully integrated cockpit. While acknowledging the fundamental importance of the flight director, the SAE Committee on Cockpit Standardization, with the concurrence of the munitions board, also includes a complete set of basic sensors in its latest standardized flight and navigational panel. The flight director presentation is of a symbolic nature. While this is necessary for rapid, accurate, decisive control, it requires the accompaniment of corroborating pictorial-type displays for redundance, warning of failure, and naturalness of presentation to establish pilot confidence and make him *want* to respond to the instrument displays. Reduced to practice, a good example of this is the Sperry integrated instrument system (Fig. 9) which provides in the HZ-1 a symbolic flight director for rapid response and a pictorial presentation of attitude (providing a pictorial analog of contact flight in the vertical plane). The R-1, an orientation indicator, is a pictorial display of the aircraft position and heading relative to the radio beam (providing a pictorial analog of contact flight in the horizontal plane). The C-6 displays heading error and radio bearing for stand-by and monitoring assurance. In addition, this is done within the framework of the SAE Standard Panel, with due consideration for established procedures. Fig. 10 indicates the signal flow of the basic servoloop system when improved instrumentation of the monitor-stand-by type is used. For simplicity, the engine and aircraft conditions and control paths are eliminated from this drawing. With future jet aircraft, these control loop paths are of vital necessity to the total servoloop aircraft control. Cross coupling between the individual aircraft axes control loops themselves are also not shown.

With extensive use of remote signal sources and with greater dependence on flight director and automatic pilot systems, more complete alarm-type methods of monitoring the total control system are necessary. Alarm-type monitors are of the Go, No-Go type such as lights and flags which, of course, can never be used for a stand-by.

For any given phase of flight it is possible to provide a number of control loops, each providing a control means capable of meeting the mission phase requirement. An example of this is shown in Figs. 11 and 12. These control loops can be categorized in the order of their stature as servoloops—accuracy, frequency response, and reliability. In general, the most comprehensive loop will be defined as the highest order loop, with contact flight and no instruments as the lowest order loop. The highest order loop is not always the logical selection for optimum control. Today, for instance, touch-down is best achieved with the elementary contact loop. A hierarchy of control loops becomes evident starting with the automatic pilot with computer, of which the human pilot is not a part except as a manager, down to the contact flight without instruments where the pilot must measure, interpret, compute, and provide the motor action for control. The addition of flight instruments to this most basic loop relieves the pilot of the measuring task, while the addition of a flight director relieves him of the need to scan, interpret, and compute, leaving simply the required motor action. Every control system should be based on a hierarchy of control loops providing the requisite monitor and stand-by type of instrumentation for mission success. In order to do this properly, an understanding of the role of the pilot from both a

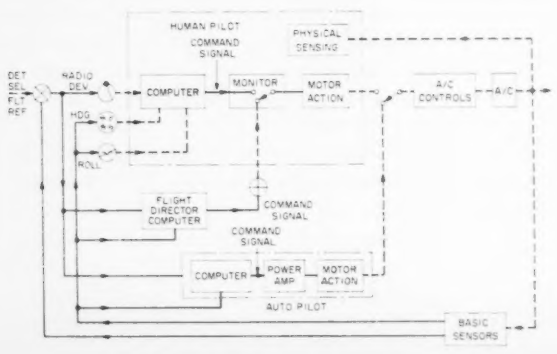


FIG 11 HIERARCHY OF FLIGHT CONTROL SERVO SYSTEM
CONTROL LOOPS

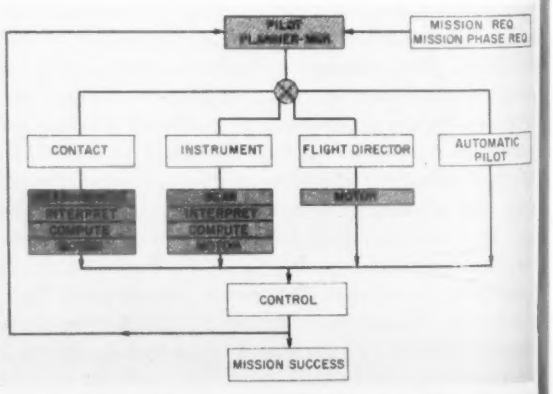


FIG. 12. Integrated control structure hierarchy of control loops

mechanistic and humanistic point of view must be established.

Conclusions

The servoanalysis method of human aircraft control investigation is a useful tool which can help to reduce flight control problems to equations familiar to engineers. The continued overall solution of the control problem, however, requires at least the combined talent of the flight operators, pilots, engineers, and psychologists from both the systems and the detailed specialists approach, involving an interplay of analysis and synthesis.

The hierarchy of control loops should be recognized and this technique used to full advantage. This means an understanding of monitor and stand-by types of instrumentation and a specific design attempt to make this instrumentation for the role it will play.

Closely tied in with monitor and stand-by are the concepts of redundancy and duplication. In addition, regardless of what control equipment the cockpit provides, there must be a sufficient display at all times to satisfy human pilot requirements. Display brings in the problem of symbolic and pictorial presentations. Even with the great strides in automaticity and instrumentation, contact flight can always provide useful information to the pilot. In fact, today the control system reverts back to contact flight at an extremely critical phase of each flight—final touch-down. This indicates the need for instrumentation that will allow this transition in control system operation with a minimum of pilot reorientation in terms of equipment controls and situation sensing.

As aircraft mission requirements continue to increase, more comprehensive instrumentation of all factors must be included as a basic integral ingredient of flight condition and control-type display and equipment. This must include measurement information on aircraft-to-earth, aircraft-to-air, and aircraft-to-aircraft relationships, as well as aircraft condition, powerplant condition, and equipment condition. As the degree of automaticity increases, more comprehensive alarm-type monitors will be needed.

True integration must recognize that, when a human cargo is involved, human pilots will be managing the aircraft. We have not yet entered the era of completely infallible equipment nor have we attained the perspicacity to forecast every possible contingency that may arise. Thus we must capitalize on the unique abilities of the human pilot in the areas of perception, improvisation, induction, long-term storage, detection, and memory—human characteristics unmatched by the most comprehensive scientific computers in existence. Far from being a burden on the system, the human pilot is nearly indispensable when his role is properly defined and when he is provided with the cockpit environment that will best enable him to play the game of strategy with the frequently unpredictable elements acting to prevent mission accomplishment. Control automation does not supplant the human pilot, but in the properly designed system it allows him to perform his duties of manager far more effectively. If a human pilot is present, he must always be in command. As an executive, he must have the prerogative of selecting the best control loop for each phase of flight, whether it be completely automatic or some combination of automatic and human control down to manual-contact. In addition, he must be provided with sufficiently comprehensive instrumentation so that he never feels that his automatic equipment is operating beyond his ability to take over. This instrumentation must make the task of monitoring automatic flight possible and manual take-over practical. In defining the role of the pilot and machine according to the unique abilities of each, a progression to simpler, more elementary, control means, inefficient though they may be, must be available to the pilot right down to the bare minimum required for him in the limit, to keep the aircraft from falling out of the sky instant to instant. Thus, the whole story still appears to center around the pilot and his role as aircraft commander. He differs extremely little from any other executive in his requirements for organization, facilities, information for decision and action, and job satisfaction.

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Some Principles of Missile Guidance

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A description of surface-to-air, air-to-air, and long-range surface-to-surface missile guidance systems and their applications, with mention of difficulties to be overcome in making such systems effective.

ATTEMPTS TO GUIDE missiles in flight date back to about 1925 when it was suggested that rockets could be made to climb along searchlight beams by means of photoelectric cells on each fin which monitored the intensity of the beam and sent signals to the rudders.† During World War II, the Germans made great strides in the development of guided missiles, but the absence of a dependable guidance system was one of their major handicaps, particularly in the surface-to-air and air-to-air applications. A relatively high degree of success was realized with the V-1 and V-2 missiles, which incorporated what amounted to a very good autopilot to program the flight along a predetermined path for a given time of flight.

Since World War II, this country, as well as all other great powers, has emphasized guided-missile development in order to exploit its rather obvious advantages as a weapon. Many approaches have been made to the problem of guiding these missiles. It can be said without reservation that there is no "simple" guidance system. While conceptually the problem is simple, the construction of accurate, reliable guidance systems which can withstand field operations is a most difficult and expensive undertaking.

Guidance systems and guided missiles in general progress through a cycle of development which is much more difficult than those of similar systems for manned aircraft. After the development, construction, and bench tests of the first few models, a new guidance system is normally flown in manned aircraft for some time, perhaps tied into the aircraft autopilot in order to simulate missile operation. On-the-spot observation and analysis of malfunctions is possible with fixes accomplished while airborne in some instances. When the guidance system is determined to be ready for flights in a missile, one is confronted with a host of new problems. If a failure occurs, destruction of the missile is virtually assured. Along with the missile, the malfunctioning part is usually obliterated. Was it the flight control system, the guidance system, the propulsion system, or the structure which was responsible for the failure? Only by continual monitoring of the signals within the missile is it possible to determine the nature of the failure. Telemetering is carried aboard test missiles to allow complete records of such tests. With the telemetering there are added new reliability problems.

Frequently, one failure will lead to other malfunctions so that the problem of untangling telemetered data to determine the source of such a chain reaction is very difficult. On the more elaborate missiles, a malfunction postpones further firing until the trouble is located and fixed on successive missiles. Time runs out quickly, but the military services do their very best to compromise logically between the time element and the cost element. The absence of personnel aboard a test missile, both to observe malfunctions directly and to fly the missile manually after a failure, is an inherent difficulty of developing and testing guidance systems.

Rather than dwell upon these difficulties, this paper will describe the various types of guidance systems and their applications. For security reasons, the details of specific missile-guidance systems obviously cannot be presented in this paper. To some of the readers this treatment may seem superfluous, but it may be enlightening to those who have not been involved in missile programs. Although the subject is not completely amenable to a breakdown by tactical applica-

Presented at the Guided Missiles Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Chief, Guidance Branch, Headquarters, ARDC.

† Gatland, K. W., *Development of the Guided Missile;* Philosophical Library, New York, 1952.

tion, this method has been chosen in order to keep practical considerations in the foreground. Three categories of guidance systems will be discussed: those for surface-to-air, air-to-air, and long-range surface-to-surface missiles.

Drones and model airplanes have long been flown by remote control using ordinary radio signals to actuate the control surfaces. This method is used to control the war-weary B-17's which are the targets for some of our test missiles. Successful control depends upon the controller's ability to observe the aircraft optically. This scheme is limited, because of the visual link, to short-range, daylight, and good weather. A rather obvious improvement can be made by tracking the missile by radar and commanding maneuvers as before by a radar or radio link. Fig. 1 illustrates the essential elements of a hypothetical command guidance system for surface-to-air missile attack upon an incoming target.* Two radars are shown—one to track the target and the other to track the missile. A computer, located on the ground, computes proper steering signals to place the missile on a collision course with the target. These steering signals are transmitted via the radar link to the missile. It is apparent that the missile must have within it a stabilized reference so that yaw and pitch signals are applied to rudder and elevators, respectively. For this reason, a roll control system or coordinate converter is included in missiles of this type to maintain a stable flight path. The steering signals sent to the missile are such that it turns at a rate proportional to the angular velocity of the line of sight between the missile and the target. This is referred to as proportional navigation and will be discussed in more detail later. The computer is faced with rapidly solving a dynamic problem in solid geometry which would be somewhat beyond the capacity of a human controller.

Fig. 2 shows a beam-riding missile.† This is the logical extension of the 1925 scheme for sending a missile up a searchlight beam. The radar beam could be produced by a parabolic reflector with a rotating dipole so arranged that the pencil-shaped radar beam sweeps out a cone with relatively low intensity along the axis of the cone, as shown in Fig. 3. Antennas on the fins of the missile could then detect differences in intensity and control the missile in such a way that it would seek the zone of least intensity in the center of the beam. The missile would fly a collision course as long as it stayed within the beam, and a minimum of on-board computing would be necessary. Homing control is shown for the last part of the flight and is desirable because of the reduced sensitivity of beam-rider guidance as the missile range increases. Rapid maneuvers of the target may place severe demands upon the control system of such a missile if it is to stay within the narrow radar beam. Once the missile is lost, recapture is difficult.

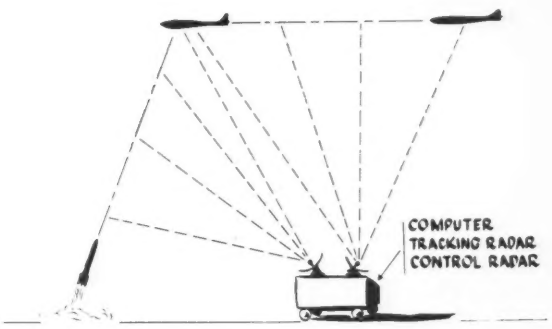


FIG. 1. Ground-based command guidance.

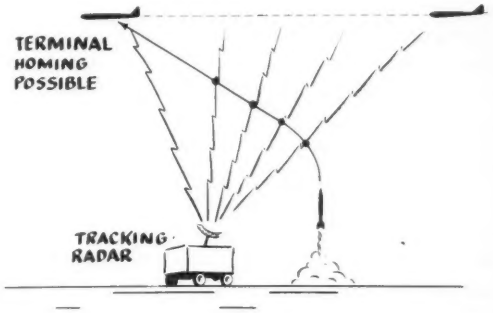


FIG. 2. Beam-riding guidance.

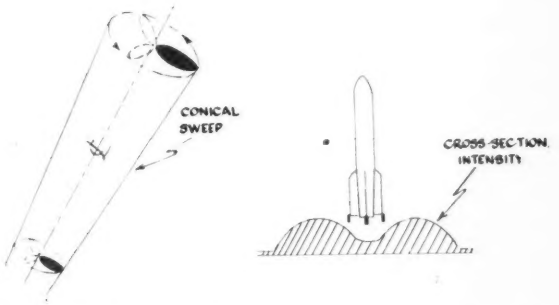


FIG. 3. Configuration of radar beam for beam-riding guidance.

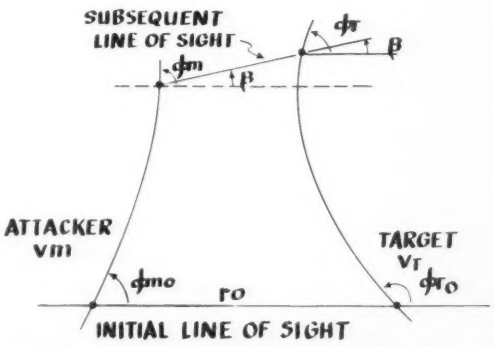


FIG. 4. Generalized air-to-air guidance geometry.

* Gatland, *op. cit.*
† Gatland, *op. cit.*

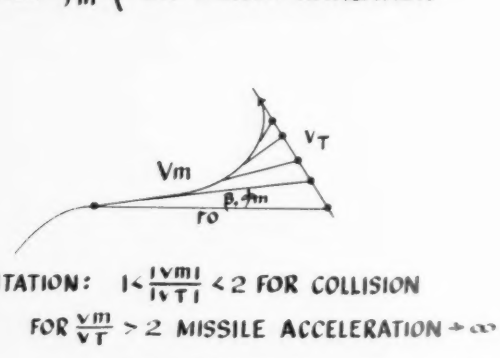


FIG. 5. First method.

The command stations are by no means limited to the ground. Provided the weight is sufficiently low, the same schemes can be applied to air-to-air missile guidance. Before proceeding with air-to-air guidance, it is appropriate to discuss the geometry associated with guiding a missile into collision with a moving target.* Fig. 4 shows a typical situation in two dimensions. The missile, or attacking vehicle, is flying the path on the left with velocity V_m. The target is on the right traveling at a velocity V_t. Contact is initially made at range r_0, and, thereafter, angles of line of sight β and of flight-path directions ϕ_m and ϕ_t of missile and target, respectively, are measured with the original line of sight as a reference.

A simple pursuit path is that followed when the missile flies directly toward the target—as a hound might chase a rabbit. It is illustrated in Fig. 5. Geometrically, such a "pursuit" course is followed if ϕ_m continually equals β. A tail chase will inevitably result, and, if the missile has sufficient endurance and speed, it will overtake the target. However, missile turning rate increases as range decreases, and, for speed ratios approaching two for a nonmaneuvering target, the peak acceleration demanded of the missile approaches infinity. A second method of attack is established if the line of sight, or bearing to target, is kept constant—specifically, zero—for the particular reference chosen above. This situation is commonly expressed by specifying that $\dot{\beta} = 0$ and is illustrated in Fig. 6. It is the course followed by the shotgun pellets fired by the hunter against the rabbit with a precomputed lead. The course flown by the attacking missile using the second method of attack is a straight line in the case of a nonmaneuvering target although considerable adjustment of the missile flight path may be necessary prior to initiating the straight-line course. However, if the target were to maneuver, the missile would be required to change course immediately in order to maintain $\dot{\beta} = 0$, thus calling for excessive lateral acceleration.

* From unpublished notes by Dr. H. Guyford Stever, M.I.T., 1952.

Both the "pursuit" course and the straight-line or "lead-collision" course—as the latter is sometimes called—have practical limitations imposed by high accelerations. A compromise known as "proportional navigation" can be used in which the missile turning rate $\dot{\phi}_m$ is made proportional to the rate of change of the line of sight $\dot{\beta}$. The steering equation can be written as

$$\dot{\phi}_m = K\dot{\beta}$$

where K, the navigation constant, is between 3 and 5 in most cases.

Missiles using proportional navigation will tend toward straight-line interception against nonmaneuvering targets and tail chase against maneuvering targets, but, in either case, the accelerations demanded of such a missile tend to remain within bounds during its entire flight.

Having determined the practical and impractical interception courses, let us identify the variables which must be measured in order to establish an interception. Although the exact trajectories followed depend upon missile and target velocities and range to target, the steering equations, neglecting the dynamics of the missile, call for the establishment of a line of sight, or direction to target, and a measure of its angular velocity in space. Range information is not necessary, assuming that it has been established that the missile can travel sufficiently far to hit the target.

The line of sight may be determined optically, by radar, by heat seekers, or by other devices capable of "seeing" or seeking the target. The fact that range is not needed allows considerable latitude in the hardware which is used for seeking. Since the rate or rotation of the line of sight is required, a gyro will inevitably be incorporated into the guidance system to establish a reference or to measure rate directly.

The last category of missile guidance is that for long-range surface-to-surface missiles. In this area, the Air Force receives many unsolicited ideas from individuals, some with considerable merit, others with less. The geometry of surface-to-surface guidance is straightforward—the missile should fly the shortest distance be-

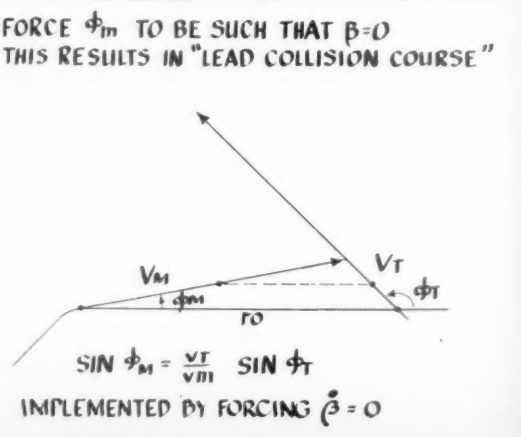


FIG. 6. Second method.

tween two points unless military considerations make this inadvisable, in which case maneuverability must be provided. The problem is to keep the missile on a predetermined course. There are, in general, two kinds of guidance for long-range missiles: those which make use of man-made navigation aids, including all radar and radio systems, and those which make use of natural phenomena. The latter would include guidance systems based upon the magnetic or electric fields of the earth, celestial information, or Newton's Laws. As an example of the man-made aids, long-range navigation can be accomplished by furnishing a missile with automatic equipment to guide on the Loran hyperbolic patterns, as shown in Fig. 7. In the Loran system, radar-like pulses are sent out by the master station and repeated by two slaved stations. The hyperbolic lines represent loci at which the time delay between receipt of the master-station pulse and "slave" pulse is constant. With two "slave" stations properly located, intersecting hyperbolae are generated which establish a navigation grid. The accuracy of the system is dependent upon the angles of intersection of the loci. For missile guidance, a system could be devised whereby the missile would fly along the locus which passes through a target meanwhile monitoring the intersecting pattern until the predetermined locus is reached which indicates arrival over the target. With more complexity, a vehicle could be made to fly any arbitrary path in such an environment. This system, while quite practical for peacetime navigation, would be vulnerable to interference signals during wartime. Depending upon the frequency of the transmitters, such a system may or may not be limited to line of sight. The maximum range of the long-wave systems is established by the interference occasioned by sky-reflected signals which degrade the accuracy.

Just as the pilot or navigator succeeds in steering an airplane from one place to another by recognition of terrain such as mountains, cities, and rivers either by visual or radar means, it is conceivable that automatic equipment could be devised for this recognition. The difficulty of such a development should not be underestimated, for among the most remarkable characteristics of the human being is his ability to recognize complex patterns. For instance, to build a machine which would recognize with acceptable reliability two different makes of automobiles, independent of distance and aspect, would be a formidable undertaking; yet this ability is developed to a high degree among relatively young children and even animals. Militarily, terrain recognition systems would have one drawback in that appropriate maps of the flight path would be necessary for territory over which reconnaissance is difficult or impossible.

Among the navigation systems based on natural phenomena are celestial and inertial systems. Celestial navigation is an art of long standing. The essential bits of information needed for celestial navigation are the angular elevation above the horizon of two or more

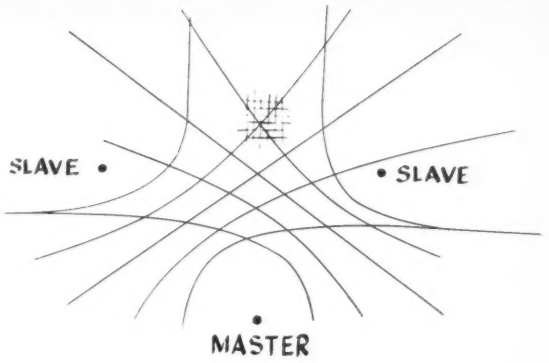


FIG. 7. Hyperbolic navigation or guidance system (Loran type).

stars and the time. From appropriate tables, lines of position can be computed and plotted on the earth's surface. The intersection of the lines is the present position. These lines must be adjusted to compensate for vehicle motion between sights if the observations are made from a moving base. With the stars as a reference, it is necessary that the horizontal plane be established or, equally applicable, the direction of the vertical. In a sextant or octant, this is accomplished with a bubble level, or it can be established by sighting on the horizon. A moving vehicle, especially if subjected to unpredictable accelerations, is an undesirable platform from which to measure the vertical since the apparent vertical, in the presence of horizontal acceleration, is tilted. An error of 1 min. of arc in the determination of the vertical results in a 1-mile error in position. An indication of the direction of the *true local vertical* is one essential element of a celestial or inertial guidance system since each point on the earth's surface, barring small anomalies, has its own unique vertical. The direction of the vertical is not meaningful unless it is established with respect to a set of known coordinates in space. These reference coordinates can be based upon the stars, which are considered inertially fixed, or upon a set of gyros which tend to remain fixed in inertial space. The third factor, time, enters the navigation problem because of the necessity of accounting for earth rotation when comparing the local vertical with the inertial coordinate system. The measurement of time, especially for short periods, is a highly developed technique. The vertical, a known inertial reference frame, and time or earth sidereal rotation are the three factors which must be considered.

The problem of indicating the true local vertical aboard a moving vehicle is not simple. The vertical, to the pilot, is simply the direction of the resultant of the gravity vector and the horizontal acceleration. For this reason, most aircraft carry artificial horizons. This instrument is a gyroscopic device which tends to erect itself slowly along the apparent vertical. For straight and level flight the task is accomplished sufficiently well, but, after a turn of long duration, this instrument may be several degrees inclined from the vertical. Even if the erection system is uncoupled dur-

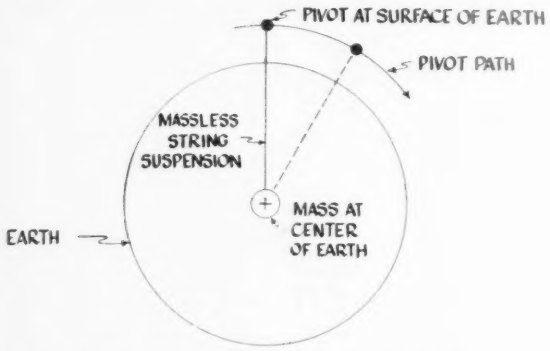


FIG. 8. Earth-radius pendulum as vertical indicator.

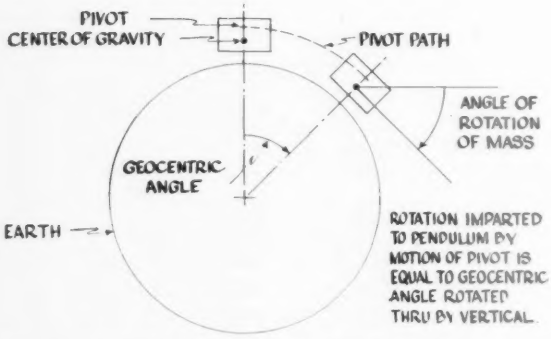
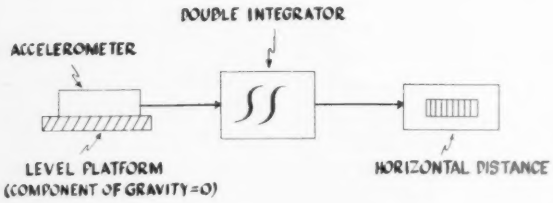

PIVOT
CENTER OF GRAVITY
PIVOT PATH
ANGLE OF ROTATION OF MASS
GEOCENTRIC ANGLE
EARTH
ROTATION IMPARTED TO PENDULUM BY MOTION OF PIVOT IS EQUAL TO GEOCENTRIC ANGLE ROTATED THRU BY VERTICAL.

FIG. 9. Schuler-tuned physical pendulum as vertical indicator.



$$x(t) = \int\int a(t)dtdt$$

FIG. 10. Inertial distance measurement.

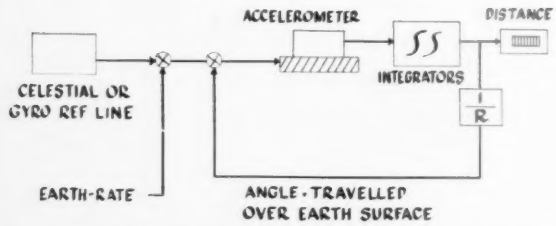


FIG. 11. Fundamental elements of celestial or inertial guidance.

ing a turn, the gyro drift will cause errors to accrue in the gyro horizon.

A simple and effective indicator of the vertical from a fixed base is a pendulum. Carried aboard the aircraft, an undamped pendulum would respond violently to aircraft maneuvers. However, as the period is increased, the pendulum becomes a better and better indicator of the vertical. In 1923 and subsequently, a German scientist, M. Schuler, published a series of papers which showed that, if the gyrocompass were built with a certain critical pendulosity, it would be immune to errors induced by horizontal accelerations. The pendulosity is such that the gyroscompass is the equivalent of an 84-min. pendulum. Directional indicators tuned to this frequency and therefore immune to the effects of horizontal acceleration are often referred to as "Schuler-tuned." Wrigley, in 1941, summarized the problem and its possible solutions in a doctorate thesis.*

Some of the interesting factors related to indication of the vertical will now be discussed. Fig. 8 shows a physical pendulum suspended by a massless string from the surface of the earth so that the pendulous mass is at the center of the earth. If one imagines a slit trench of the necessary proportions, it is quite apparent that, as the pivot is moved along the surface, the mass is not disturbed, and the string indicates the vertical. The period of such a pendulum in a uniform gravitational field of 32.2 ft.²/sec. would be 84.4 min., according to the familiar equation $T = 2\pi\sqrt{l/g}$. It can be shown that a pendulum with an infinite length suspended so that the mass just grazes the earth would also have an 84.4 min. period for small oscillations. Similarly, a mass placed on a plane surface tangent to the earth would slide back and forth with a period of 84.4 min. in the ideal case, neglecting friction. A physical pendulum is shown in Fig. 9 consisting of a mass suspended so that the center of gravity is a very short distance below the effective pivot point. With proper construction, long periods can be obtained, but, if the necessary computations are made to establish an 84.4-min. period, it is found that the distance between the pivot and center of gravity is of atomic proportions for masses of reasonable size. Although impractical, such a physical pendulum would maintain the vertical if the pivot were accelerated horizontally.

Returning to more practical realms, the high angular momentum of a gyro allows the construction of a pendulous device with the necessary periodicity as achieved in the gyrocompass. It is also possible to set up a second-order system on an analog computer and so adjust the gains as to achieve this period artificially. Recent articles† have described the possibility of constructing practical inertial navigation systems using the principle of Schuler tuning.

* Wrigley, Walter, *An Investigation of Methods Available for Indicating the Direction of the Vertical from Moving Bases*, Doctorate Thesis, M.I.T., 1941.

† *Aviation Age*, Vol. 22, Nos. 2–5, 1954.

In order to measure distance traveled, it is possible to mount an accelerometer on a horizontal platform so that it picks up no component of gravity, to double-integrate the output of the accelerometer, and to indicate the distance traveled on the output shaft, as shown in Fig. 10. Note the desirability of keeping the platform horizontal during the motion. Also note the fact that, if appreciable distance is traversed, the horizontal plane or the local vertical changes direction appreciably, and the platform is tilted with respect to the new local vertical. The distance indicator would thus become worthless. If mounted on a railroad car on a good level track, it might be acceptable as distance indicator since the track would retain the horizontal as it went across the surface of the earth. In an aircraft, one could slave the platform to a gyro-stabilizing device, as is shown in Fig. 11, feed back the distance traveled in terms of the angle of the vertical, and therefore tilt the platform with respect to the stable gyro just enough to retain the local vertical. In conjunction with this operation, one must also compensate for earth sidereal rotation. If the second-order loop, as illustrated, were disturbed by an extraneous signal, it would be found to oscillate with an 84.4-min. period. It represents an elementary navigation system which, if set up properly at a starting point, will indicate the distance traveled along a straight-line or great-circle course. By combining two such systems, motion could be measured in two mutually perpendicular directions on the surface of the earth.

In proceeding to the closed-loop system shown in Fig. 11, there have been added to Fig. 10 two remaining factors mentioned earlier as being necessary: a reference coordinate system, and time, or earth rotation. It is apparent that, from a functional standpoint, it makes little difference whether the reference unit is a gyro or an automatic star-tracking servomechanism. The ability of either to hold its orientation is extremely important. The problems involved in the realization of low gyro-drift rates and the precision which is required in all of the components for inertial and celestial systems, such as accelerometers, gear trains, integrators, etc., are a challenge to engineers and machinists alike. Star trackers properly designed will lock onto stars as long as they are above the horizon and will hold without drifting. It is necessary to track a minimum of two stars to establish the celestial reference. However, if the celestial reference is used, one is confronted with problems of cloud cover or loss of stars for other reasons, which would render the system useless. A combination of gyros and star trackers would ease the basic problems but would increase the complexity of the device quite markedly.

Added to the equipment already described is the computational equipment necessary to steer the vehicle automatically from information provided by the navigation unit and to compensate for extraneous forces. For instance, a body moving with a velocity V in a rotating coordinate system experiences a coriolis force which is proportional to the vector cross product of V and the rotational vector W—in this case the spin velocity of the earth. If the accelerometers were not biased for the coriolis force, it would be found that a vehicle flying due south along a meridian in the Northern hemisphere would indicate an eastward component of acceleration which is actually not present in terms of motion with respect to the earth. By appropriate choice of coordinate system, coriolis forces can be avoided, but other complicating forces arise. There are other extraneous conditions which will lead to small errors unless compensated. The existence of complexity in such a system is inevitable. Again, it should be stressed that, even though the concept may be simple, there is no such thing as a "simple" guidance system.

The Air Force is achieving an appreciable degree of success in developing systems based on principles discussed in this paper. Industry and educational institutions have worked hand in hand to overcome the formidable problems encountered in making the step from the rudimentary guidance systems such as those developed in Germany in World War II to the systems which are under development today and which will make *each missile count.*

Reliability, accuracy, and ease of maintenance must be considered early in every development program if an effective system is to be realized. Reliability is receiving considerable attention and remains a serious challenge to the designer. There may be a point of diminishing returns in the investment of additional money in improving reliability in an already expensive missile, but few, if any, missile engineers would venture to suggest that the optimum point has been reached. There remains considerable advantage in 100 per cent inspection of missile vacuum tubes to arbitrary mechanical and electrical specifications more stringent than MIL E1B, the official specification for tubes. The second factor, accuracy, is one of the primary objectives throughout development. Compromises can be made among guidance accuracy, warhead size, and fuzing in arriving at design objectives for the guidance accuracy. Ease of maintenance is a factor normally associated with systems which are operated repeatedly or continually—such as manned aircraft, communications, and bombing equipment. Especially in large missiles which must be in "ready" condition for long periods of time, it is important that failures be easily detected and remedied. It must be appreciated by all concerned in the missile program that a weapon which reaches the field and cannot be made to "kill" a target is worse than no weapon at all.

Active work on the part of both electronic and airplane designers is required to set up standards of electronic equipment cooling that will provide the best aircraft performance.

The Problem of Cooling Electronic Equipment in High-Performance Aircraft

Nathan A. Carhart*
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THE EVOLUTION of military aviation has produced aircraft of extremely high performance carrying an ever-increasing load of electronic equipment. This electronic equipment is by its very nature energy consuming. Its efficiency measured as "power out" vs. "power in" is often low. It is consequently heat producing. Its tolerance for heat is limited. The natural environment provided within a high-performance aircraft is widely variable. It is the intention of this paper to discuss the present and near future environment of our aircraft and to suggest a means for achieving greater aircraft efficiency by defining more clearly heat-transfer requirements which could produce more coordination between the aircraft manufacturer and the electronic industry.

Weight is of primary importance to the aircraft designer. The size of an airplane is in direct proportion to the amount of pay load that it is designed to carry. For purposes of this discussion, pay load consists of those elements of an airplane exclusive of the structure, flight controls, engine, and fuel. Present-day high-performance combat aircraft accommodate a design pay load of approximately 10 per cent. For equal performance, airplane size must be modified by a growth factor (Fig. 1) applied to the weight of items constituting the pay load. Substantial overall savings may be made through reductions in equipment weight.

Aircraft environment is a variable. Static temperatures vary from above 100°F. to below −100°F. Operating altitudes range from sea level to above 50,000 ft. Fig. 2 defines approximately the speed-altitude range of existing combat aircraft. Both speeds and altitudes are well below values already existent for record purposes.

Aerodynamic heating can be defined as a raising of the local air temperatures due to energy acquired from a change in the velocity of the air. Any air brought into the airplane has its relative velocity changed by substantially the total velocity of the aircraft. The temperature rise associated with Mach 1 is approximately 100°F. Additionally, the change in velocity produces a pressure change. Fig. 3 plots the temperature pressure environment to be expected within aircraft as defined by the previous figure. Temperatures per AN-A-421 are the bases for establishing limits as used throughout this paper. The pressures shown include an allowance for intake losses and do not, therefore, show full ram recovery. Superimposed is a plot of the temperature requirements specified for electronic equipment by Mil-E-5400. The extent to which we are already beyond what standard equipment is required to take should be noted.

What of the future? Mach 3 aircraft are spoken of almost casually these days. Suppose we examine the environment of such a plane. Fig. 4 shows the speed-altitude envelope of an airplane with a ceiling of 70,000 ft. whose high speed varies from Mach 2 at sea level to Mach 3 at 35,000 ft. For comparison purposes, the limits from our previous example are also shown. Fig. 5 is a plot of the pressure-temperature environment

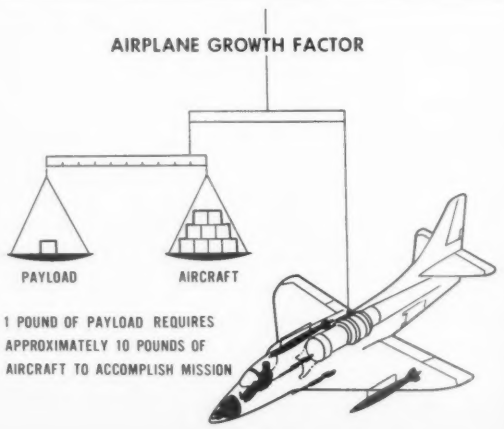

FIG. 1.

Presented at the Electronics Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Design Engineer.

within the aircraft. It illustrates the extremely rapid rise in temperature to be encountered with increasing speeds.

An examination of methods available for cooling electrical equipment has led to the choice of three as being representative. Shown in Fig. 6, they are capable between them of covering a wide range of environmental conditions. Simplest is ventilation through the use of ram air. The temperature-pressure envelope of the aircraft establishes the inlet conditions to which the equipment will be subjected. Where equipment can be designed to operate within this limit, there is great advantage in so doing since this is the simplest and consequently the most reliable method of cooling. Care must be exercised so as not to incur excess drag (and hence weight) penalties in the design of such a system.

Normally, aircraft are not operable at their maximum conditions except for short intervals. Where equipment approaches an ability to operate at extremes of the ram air envelope, it may be possible still to use ram cooling if, for short periods, advantage is taken of the heat sink inherent in the mass of the electronic gear itself. Some representative present-day equipment requires 8 watts per pound of weight. Based on the specific heat of copper, this heat input will raise the average temperature by 50°F. within 10 min. This would obviously be good for only a limited period. Unfortunately, as the power density of the equipment increases the chance of obtaining any usable heat sink in the equipment is minimized. Some other type of heat sink carried in the aircraft may be of benefit. Water or liquid oxygen could be injected into the ram air for short periods of maximum performance.

As noted previously, present standard equipment is not required to operate at ambient conditions experienced under maximum flight conditions. An air cycle system can provide adequate cooling to meet specification requirements within existing performance envelopes. Such a system consists of a heat exchanger and power turbine utilizing bleed air from the jet engine. High-pressure, high-temperature air is led through the heat exchanger where its temperature is reduced to some value still above ambient. Further reduction in temperature is obtained by employing this cooled air to produce work in driving a mechanically loaded turbine. This turbine exhaust becomes the cooling supply. That this is not an ideal system may be deduced from the following. At Mach 1 it requires approximately 15 lbs. of cooling apparatus plus a maximum of 22 kw. of power from the aircraft engine to remove 1 kw. of heat from equipment that must operate within the ambient limits of Mil-E-5400. Fuel expended on a 2-hour mission at cruise conditions is 17 lbs. per kw. Adding installed weight and fuel requirements shows that 1 lb. of refrigeration will supply but 32 watts of cooling capacity. At a figure of $400 per pound, which is based on use of the growth factor concept, the dissipation of 1 watt costs $12.50.

We shall eventually operate aircraft under conditions of outside pressure sufficiently low that air cooling

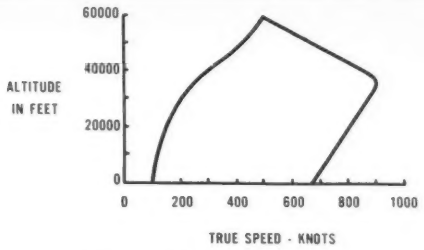

FIG. 2. Combat aircraft limits.

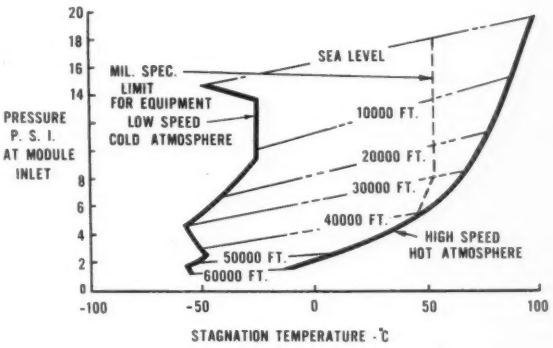

FIG. 3. Existing environment.

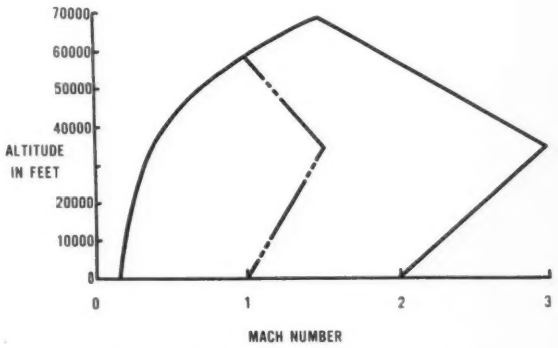

FIG. 4. Predicted envelope for Mach 3.

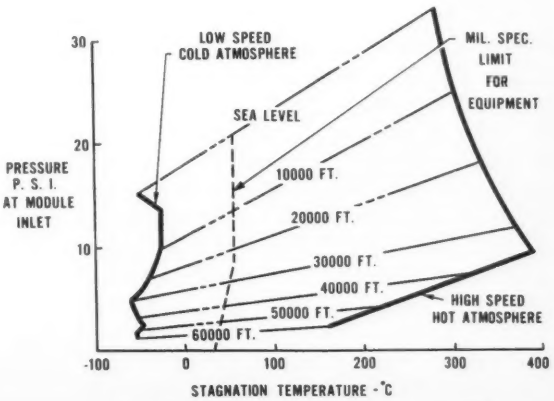

FIG. 5. Predicted environment.

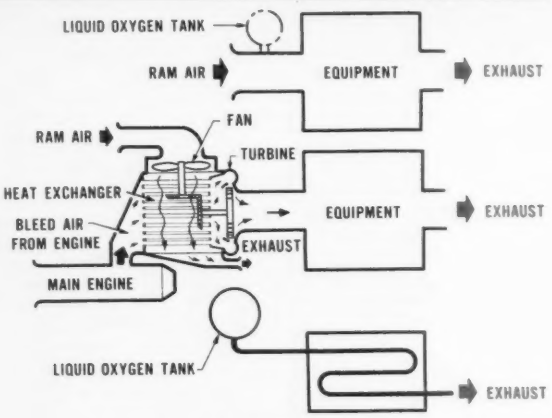

FIG. 6. Cooling systems.

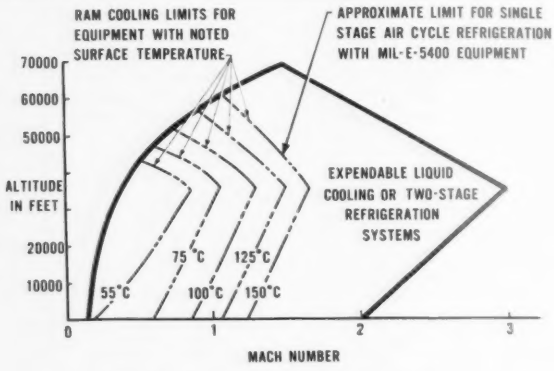

FIG. 7. Limits for cooling equipment.

becomes impractical. A heat sink must be found on board the aircraft. Since great quantities of fuel will undoubtedly be carried, it would seem at first glance to be a most logical heat sink. Because of stringent fuel inlet temperature limits on the engine, it appears improbable that any great amount of heat can be liberated to the fuel. Some of our existing aircraft that use fuel for cooling the hydraulic system have already pushed this limit to the utmost. Vaporization of some liquid will probably offer the most practicable heat sink per unit weight. The vaporization of 1 lb. of water at 55°C. requires about 1,020 B.t.u.'s. This is equivalent to the heat generated by dissipating 300 watt-hours of electrical energy. Unfortunately, water is not ideal since it is prone to freezing. Liquid oxygen will probably be available in quantity as it is coming into use for crew breathing. Specific heat is low, but, as the boiling point is approximately −162°C. at 70 psi, a single pound of oxygen can absorb 55 watt-hours from equipment that is limited to 100°C. In a typical system, the heat-generating equipment would be placed inside a hermetically sealed can incorporating heat exchanger passages through which is passed the coolant. Resulting vapor is bled overboard. The ultimate capacity of this type of system is limited only by the amount of liquid which may be carried. Many modifications and combinations are possible.

Envelopes describing probable operating limits for these systems are shown in Fig. 7. A ram air system for 150°C. equipment is equivalent to a single-stage refrigeration system for Mil-E-5400 equipment. Unless equipment operating temperatures can rise at a rate to balance rises in temperature due to increased aircraft performance, refrigeration will be a necessity. The complexity of the refrigeration system will be minimized by use of the highest possible operating temperatures. Energy cost (and hence fuel weight) is also reduced regardless of the cooling system chosen.

Any electronic equipment operated in an aircraft requires electrical energy which is normally produced at the time of its use. Constant frequency a.c. power has become increasingly common. Fig. 8 plots weight per kva. against cooling air temperature at two different altitudes for the installation of a Class C 20-kva. blast-cooled alternator including its constant speed drive. Installed weight is a function of inlet temperature at constant altitude. Points marked on the curves show approximate operating limits for existing airplanes. The reduction in air temperature with altitude is sufficient to provide the same output per pound in spite of a lower air density. Energy for driving the alternator is obtained through the burning of fuel in the main engine. As this energy is converted a number of times before it becomes electrical, 3 lbs. of fuel may be required to develop 1 kw.-hour of electrical energy. Additional energy is required to force air through the alternator. The alternator at rated output requires only 1/2 lb. of air per min. per kva. Under cruise conditions, 2.5 lbs. are actually supplied. The drag loss for this quantity of air is equivalent to 1.25 lbs. of fuel per hour. A 2-hour mission would require per kva. an installed weight of 7 lbs. plus a fuel cost of 8.5 lbs. [(3 + 1.25) 2] for a total of 15.5 lbs. This is equivalent to saying we can provide only 65 watts of electrical energy per pound of supply weight.

It is apparent that the energy demands of electronic equipment result in significant amounts of weight. At $400 per pound, as previously quoted, the energy

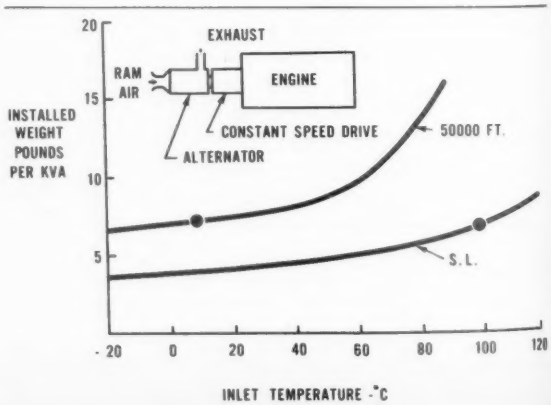

FIG. 8. Power generation.

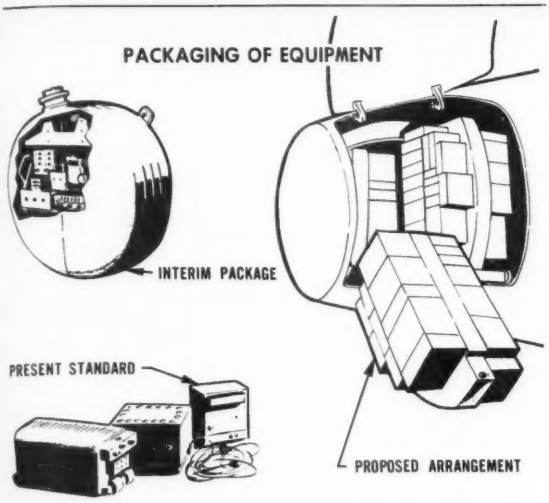

FIG. 9.

supply costs $6.00 per watt. Adding this to the cost of cooling results in a figure of $18.50 per watt. A premium of this magnitude can well be paid for more efficiency in energy utilization within the electrical equipment.

The ever-increasing demand for additional electronic functions is posing a difficult design problem in space utilization. An investigation is under way to develop an integrated electronic configuration for an existing combat aircraft. This airplane was designed on the basis of minimum size and minimum weight. Early models carry a limited amount of radio, navigation, and armament control equipment. Even so, available space was at such a premium that a certain amount of repackaging was required. An interim solution consisted of repackaging three pieces of existing GFE (Government-Furnished Equipment) into a single package (Fig. 9). The integrated configuration visualized will include all existing functions and will add appreciably more equipment in the form of navigation and armament control devices within the same outer envelope.

Fortunately, electronic manufacturers have already begun to anticipate some of our needs. Through miniaturization, transistorization, and more effective space utilization, they have opened the door to the possibility of including within the limited volume all of the functions that are desired. In addition, some of this equipment is already being produced in modular form. The modules consist of plug-in subassemblies packaged within certain dimensional standards which may, by revising the support chassis and wiring, be combined into complete functions of variable shape factors. The integration program, if fully implemented, must exploit these features. It will provide a fresh start for an appreciable number of equipments.

It appears desirable to survey the cooling requirements in considerable detail. As previously noted, the temperature limits for electronic equipment as specified in Mil-E-5400 are considerably below the ram temperature limits in existing aircraft. Individual components of electronic equipment are known to operate successfully with temperature environments considerably in excess of these values. It is, therefore, conceivable that we should obtain equipment which will be suitable for operation without a refrigerated cooling supply.

The use of refrigerated air for cooling has had a noticeable effect on the arrangement of equipment within our combat aircraft and on its accessibility for maintenance. Where compartment temperatures must be below the existing ram air environment, extremely limited leakage into the compartment can create an appreciable increase in the heat load which a cooling system must absorb. Fig. 10 shows heat load added as a function of leakage rate for an airplane with a compartment temperature limited to Mil-E-5400. At pressure differentials possible across the aircraft skin, a 1/4 in. diameter hole will leak 0.875 lbs. of air per min. At Mach 1 this is equivalent to a 30-watt source. Leakage may be minimized by limiting the number of access doors. It becomes necessary to provide exceptionally

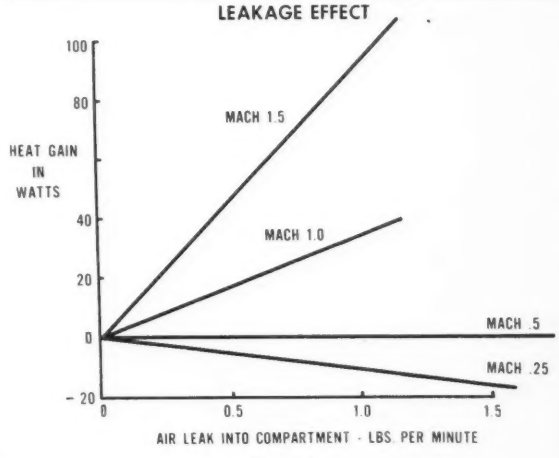

FIG. 10.

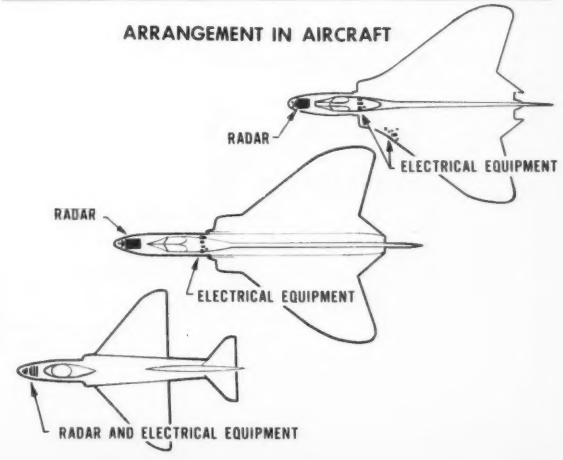

FIG. 11.

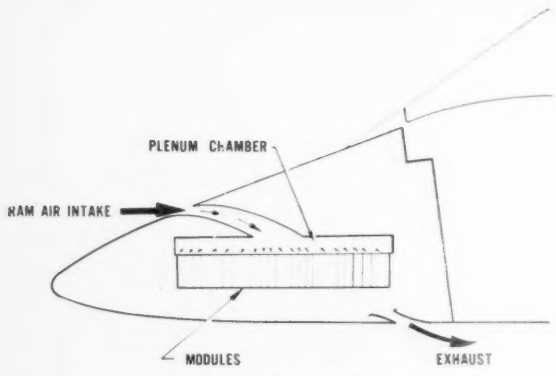

FIG. 12. Cooling of module.

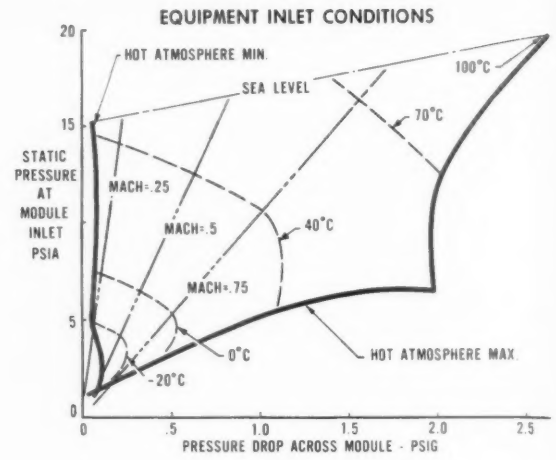

FIG. 15.

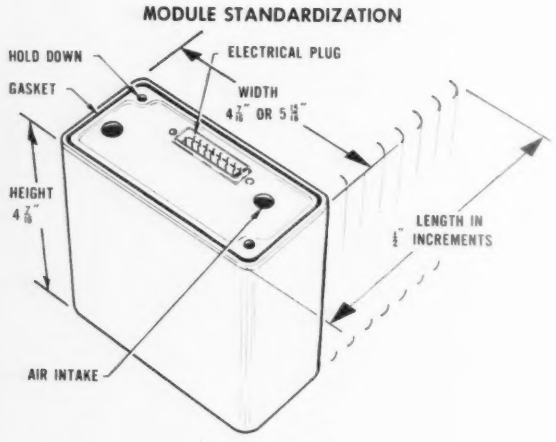

FIG. 13.

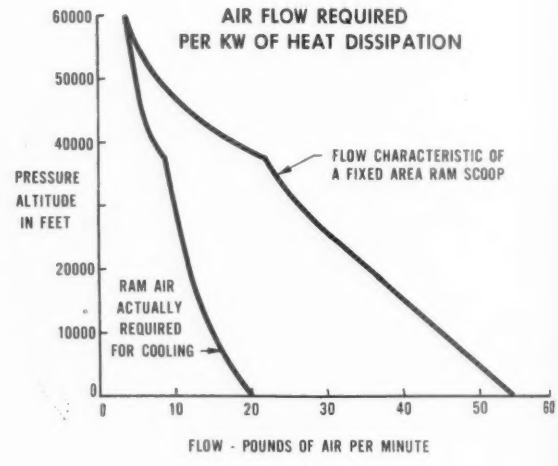
AIR FLOW REQUIRED PER KW OF HEAT DISSIPATION
FLOW CHARACTERISTIC OF A FIXED AREA RAM SCOOP
RAM AIR ACTUALLY REQUIRED FOR COOLING
PRESSURE ALTITUDE IN FEET
FLOW - POUNDS OF AIR PER MINUTE

FIG. 16.

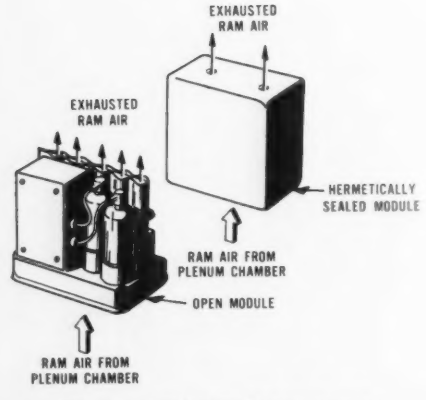

FIG. 14. Typical module treatment.

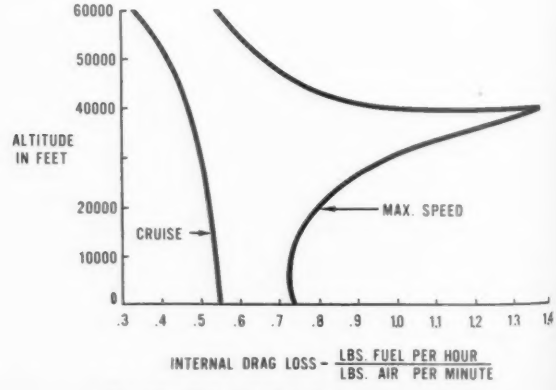

FIG. 17. Internal drag loss for ram air.

good seals on such doors. Internal sealing must also be of a high order. In short, sealing standards are close to those required of cockpits. To provide the necessary design control we have concentrated more of the electronic equipment into a single compartment (Fig. 11). This trend, although started because of the critical nature of refrigerated cooling, will probably continue because it can simplify the cooling system regardless of the type. With a ram air system where leakage is unimportant to the operation of the cooling system, it is possible to relax sealing requirements. This can help to provide, through larger and more easily operable access doors, a higher order of maintenance and reliability.

Elements of a simple ram air system are illustrated in Fig. 12. Cooling air is drawn in through a flush duct and distributed to the various modules through a plenum chamber which doubles as chassis and wiring trough. After passing through the modules, the heated air is exhausted overboard.

In order to rationalize requirements and set up specification standards for discussion with electronic manufacturers, we have made certain assumptions:

(1) Ram air cooling is feasible, for at least the immediate future.

(2) The airplane manufacturer should supply some standard quality of air to each module. Weight flow per module shall not exceed a given value per watt.

(3) The electronic manufacturer should so design those modules which require cooling that they incorporate suitable heat-transfer passages for efficient use of the air supply.

To accomplish such coordination between airplane and equipment manufacturers, it will be necessary to standardize on certain design features for the modules. This includes, in addition to the basic dimensional standardization, a suitable scheme for transfer of air to the module. Fig. 13 is the first approximation of a possible approach. Essential features are some form of gasketed surface to control air leakage and predetermined resistance in the air passages to provide suitable impedance matching of the air supply network which is necessarily in parallel through the modules. To achieve the necessary space utilization, modules may be mounted within 1/16 in. of each other. Heat-transfer passages must not extend beyond a projection of the base dimensions. The effective case temperature of elements with high heat dissipation must be limited so that heat is not radiated to the other modules. All cooling is assumed to be by air convection within the module and not by radiation or conduction to other parts of the aircraft. Fig. 14 depicts suggested heat-transfer methods for both sealed and unsealed modules. Choice of an actual heat-transfer configuration should be made by the electronic equipment designer. The heat-rejection requirements and their solution are subject to engineering techniques which are often analogous to those already in use in electrical design. Any optimum solution will be obtained only when good electrical, mechanical, and heat-transfer engineering are combined at a single location. Suitable design compromise and architectural integration will result in a product that requires less installed weight and which has a much higher order of reliability.

This cooling system is defined by four variables:

(1) Absolute pressure at the inlet port of the module.
(2) Pressure drop across the module.
(3) Temperature.
(4) Weight flow.

A plot of the first three in current aircraft is shown in Fig. 15. This is a replot of previously shown information but with the addition of pressure drop. Values of pressure drop do not include intake and exhaust losses so that they define only the drop across the cooled equipment. The pressure curve is that to be expected at the equipment inlet. Temperatures are those for hot day conditions exclusively. A maximum temperature of 100°C. is realized but only at maximum conditions of pressure and pressure drop. Since weight flow is highest at these conditions, it develops that other combinations within the envelope result in higher stabilized temperatures for the equipment. Weight flow per kw. of equipment heat dissipation is determined by the formula

$$W = 237.5/(T_2 - T_1)$$

where

W = weight flow, lbs.
T_2 = outlet air temperature
T_1 = inlet air temperature

Inlet air temperature is fixed by flight conditions. Outlet air temperature is the variable over which the equipment designer has some measure of control. He may modify it both by the effective temperature at which the equipment may be operated and by the efficiency with which heat is transferred to the cooling air. Reduced weight flow is obtained by increases in either or both of these factors. Equipment should be run at the highest practical temperature. Heat-transfer practices should be such as to develop the highest possible outlet air temperature. Although this must always be something less than the effective equipment temperature, proper arrangement of components, with respect to the airflow path, can do much to making it a maximum. Heat should never be conducted by the airflow from components with a high heat tolerance to those with a low heat tolerance. Control of local air velocity is a major factor in its ability to conduct heat.

Airflow requirements, based on 25 per cent efficiency and an effective module temperature of 125°C., are shown in Fig. 16. Required weight flow changes by a factor of two over the altitude range. This reflects the increased air temperature at lower altitudes. As noted above, reductions in this required weight flow are quite possible through increases in both efficiency and effective operating temperature of the equipment. Doubling heat-transfer efficiency and raising the effective operating temperature to 150°C. would reduce these

(*Continued on page 109*)

H. I. Rothrock*
Office of the Chief of Naval Operations

Navy Requirements for Air Navigational Aids, Communications Facilities, and Air Traffic Control, 1955–1975

A discussion in the light of the dual nature of Naval aviation operations—flying in the Common System over land and in the tactical system at sea

A BASIC UNDERSTANDING of the Navy's mission is necessary for an accurate appreciation of the Navy's requirements in the fields of air navigational aids, aeronautical communications, and air traffic control services. The National Security Act of 1947 states, in part, that the ". . . United States Navy shall include naval combat and service forces and such aviation as may be organic therein. It shall be organized, trained, and equipped primarily for prompt and sustained combat and service training forces, and shall include land based naval aviation and air transport essential for naval operations . . . ." Obviously, though primarily concerned with combat over the sea, the Navy's air arm must operate from and over the land.

The dual nature of our operating requirements leads to complications faced neither by the other military services nor any civil organization. The Navy conducts all of its basic training and the majority of its operational training from bases established ashore within the United States. Its new aircraft are delivered over the nation's airways, and aircraft being returned for overhaul are flown over the same routes. Administrative and logistic flights are conducted into and out of scores of airports—military and civil—located in every state in the Union. To conduct these operations with the maximum of safety and expedition requires that our aircraft be fully equipped to operate in the Common Military/Civil System. This system, as presently implemented, consists of not less than eight different navigational facilities of several different types and communication equipment operating in five distinct parts of the frequency spectrum. To participate in the Common System, the naval pilot must be able to navigate as accurately and communicate as efficiently as any civil pilot. However, the evolution of the Common System has been guided, basically, by civil rather than military requirements; consequently, it is more suitable to the needs of the civil rather than the military pilot.

While the Navy must fly in the Common System, its air arm basically has been designed for operation with the fleet at sea. Here it faces a radical change in operating concept, for ability to meet and defeat the enemy rather than safety of operations is the prime requirement. Operating speeds and altitudes are high, and the time in which a satisfactory intercept can be made is all too short. The navigation system must be capable of being installed on a single ship. It is desirable to intercept the enemy at maximum range, but it is at maximum range that the aircraft's displacement from the desired position is the greatest due to navigation system errors. Thus we have a tactical requirement for a system azimuth accuracy in the neighborhood of 1/2 deg. whereas the common system presently functions under accuracies no better than $3^1/_2$ deg.

Thus we find that we have two valid but different requirements for navigation service which are dictated by the types of operations in which the same aircraft must take part. Because of these basic differences, the system that satisfies present civil requirements may fail to meet our tactical requirements by a wide margin. Add to this the requirement for the expeditious establishment ashore of the basic tactical aid during the early stages of an amphibious operation and the requirement becomes difficult of resolution.

To a greater or lesser extent the same parallels may be drawn between the Common System and the naval requirements for communication and air traffic control where different types of operations and environments have evolved radically different solutions to the same basic problems. For example, the Common System communication services are found in the low, medium, high, and very high frequency bands with ultra high

Presented at the Air Transport Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

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frequency facilities being installed specifically for the military services. Privately owned aircraft may have a transmitter capable of operating on from one to five or ten channels. Business and air-line aircraft are equipped to transmit on up to 150 preset channels, and air-line equipment now under procurement will provide from 250 to 500 channels. All naval tactical aircraft can transmit on 19 preselected channels and, on a manually selected basis, on any one of 1,750 channels in the UHF band. It is obvious that air-borne equipment is procured on the basis of the type of operation in which it is to be used.

When, as in the case of naval aircraft, it is necessary to fly in both the Common System and the tactical system, the matter of the electronic configuration in the aircraft becomes very difficult and, based on certain solutions, very expensive. To fly in both systems requires that the aircraft alternatively (1) carry the air-borne components required in each system, (2) change from Common System equipment to tactical equipment when scheduled to engage in operational training or to operate tactically, or (3) carry its tactical equipment at all times and such Common System components as are required to give minimum performance on the airways.

The first alternative is completely unfeasible. The cost per aircraft for low and very high frequency navigation and marker beacon receivers plus automatic direction finder and distance measuring equipment in addition to the tactical navigation equipment is approximately $10,000, not including several thousand dollars per aircraft chargeable to installation. Based on the average annual Navy/Air Force procurement of tactical aircraft, this would amount, annually, to many millions of dollars above present costs. The additional weight—approximately 250 lbs.—would require an increase of "all up" air-frame weight of approximately 2,500 lbs. About 10 lbs. additional air-frame weight results from increasing structural strength, extra fuel, extra power, etc., for each pound of equipment required to provide the originally planned performance with the greater load. If added to existing aircraft, it can be done only at the sacrifice of tactical capability.

The second alternative is impracticable from the logistics standpoint. To make this system work requires special configuration of the aircraft so that either of two dissimilar systems may be installed on a quick-change basis and additional manpower to make the changes. It also requires that the proper set of equipment be at the proper place at the proper time. This last requirement is difficult in itself as the aircraft that goes aboard the carrier today may return next week or next year and not necessarily to a station on the same coast.

The third is the only feasible alternative, and it falls short of a satisfactory solution. The majority of the elements of the Common System were designed many years ago for aircraft of much lower speed ranges than today's military aircraft. This now results in serious problems of antenna installation and drag on transonic and supersonic aircraft. In addition to physical limitations, electrical disturbances have developed in these ultrafast aircraft that are not present to the same degree in slower aircraft. The overall effect of partial implementation and of something less than full reliability is an unsatisfactory bad weather capability and a derogation of safety and facility of movement.

In the matter of air traffic control, the Navy again faces a dual requirement. It must submit to traffic control in the Common System while flying ashore, and it must have a traffic control system of its own to provide the maximum degree of safety in operations at sea.

Air traffic control originated in the United States in 1937. The system was designed to operate with the equipments then available and in a manner compatible with the type of route navigational aid implementation then in effect. Simplified, traffic control is applied by dividing the controlled airspace into horizontal slices, each 1,000 ft. thick, so that an aircraft can be assigned to a specific altitude for protection against other aircraft in the same general airspace. The route is divided longitudinally by the navigational aids themselves or by the intersection of courses generated by these aids. Under instrument flight rules, pilots must report their progress along the route by reporting when they are over certain "fixes" defined by the navigation aid. This provides a system of "gates" through which the traffic controller will clear the aircraft only if the block of airspace ahead and at the same altitude is clear of conflicting traffic. This also provides the basic system of separation during changes of altitude when one aircraft must climb or descend through altitudes occupied by other aircraft.

The traffic control system makes use of voice radio in the reporting of aircraft position and in the transmission of control instructions from controller to pilot. Interphone and teletype circuits are used to interconnect traffic control centers, airport towers, operations departments at military airfields, etc. With the exception of the automatic teletype circuits, all communications are manually conducted and quite slow. Because of the low rate of information transfer by voice radio and the large amount of information to be processed, an inordinately large number of communication channels are required.

This system was entirely adequate, in both speed and capacity, to control the air traffic of 1937–1941. Had it not been for World War II with its accents on research, design, and use of aircraft, our traffic control system would probably have been adequate for many years. As it turned out, we outgrew the system capacity long before the end of the war. While safety of flight was maintained, it was accomplished at the expense of traffic flow. For example, in 1945, the landing intervals at LaGuardia Field were averaging between 12 and 15 min. Other heavy traffic areas were equally restricted.

A determined attack was made on this problem by the Civil Aeronautics Administration and users of the airspace. With the installation of approach control, direct communication between traffic controllers and

pilots, and peripheral communications and radar, the ability of the traffic control system to cope with our large terminal area requirements has increased to such a degree that at Washington and Chicago the traffic flow under instrument conditions closely approaches the area fair weather capacity. The New York area, because of its greater complexity, is still somewhat behind, but it has improved markedly.

From the foregoing discussion, the conclusion might be drawn that the traffic control situation is rapidly clearing up and that within a short time our troubles will be over. This is not so. Unfortunately, the traffic at our largest terminals consists mainly of commercial airliners, business aircraft, and equivalent military types which are engaged in operations of a logistic nature. High performance tactical aircraft of short flight duration are seldom included in this operation because of the inherent incompatibility between the basic methods of controlling traffic in the Common System and the requirements for safe and efficient operation of jet aircraft. In order to realize the high performance capabilities of the jet, it is necessary that it operate at high altitudes as much as possible. This means rapid climbs to and descents from cruising altitude. Having descended from high altitude to a level of 15,000 or 10,000 ft., the jet is committed to land. The amount of fuel remaining is usually small, and the fuel consumption at low altitudes is high. These conditions preclude devious routings and holding in traffic patterns. Except at a very few locations where radar permits more flexible operation, the present traffic control system cannot cope with the jet in the presence of piston engine aircraft with the requisite degree of efficiency. This is undesirable even from the military standpoint, as other military aircraft are often held up to permit the approach and landing of jet aircraft. This condition will rapidly grow worse, as commercial jet transports are just around the corner and the military trend is toward larger and faster jet aircraft in all categories.

I would like to recapitulate my presentation to this point. Unlike other services, the Navy is faced with the dual requirements for sustained operations over land and water. The Navy's requirements for navigation accuracy are far more rigorous, tactically, than are those of civil aviation. Because of this, it is practicable to meet civil needs with less expensive, less complicated, and less accurate equipment. However, civil requirements more than military requirements have, in the past, dictated the development of the Common System. Since the original development of air traffic control, a major war has accelerated aircraft development and use to such an extent that, at the conclusion of that war, the traffic control system had been rendered obsolete. Although seriously lacking in flexibility, it has been improved in the last 10 years; present traffic figures show that, at Washington, Chicago, and, to a lesser extent, New York, the instrument flight rule traffic is being handled in a quantity comparable to clear weather operations. It was pointed out that these figures cover air-line, business, and military logistic aircraft but that the high-performance, tactical aircraft do not—nor are they generally able to—get into this type of operation, as it is incompatible with the type of operation for which they are designed. Finally, it was pointed out that, if the present navigation features of the Common System are to be incorporated in all tactical aircraft, it will be at heavy cost to the taxpayer and will entail sacrifice of tactical capabilities.

At this point, one might well conclude that meeting the Navy's requirements constitutes an impossibility. This is true if we consider only those things that can be accomplished in the next few years. It will not be true in the more distant future if we coordinate the requirements of all users of the airspace and then make a concerted attack on the technical and operational aspects of the problem. The Navy cannot solve its problems in a vacuum. It cannot demand that its requirements be fulfilled without being willing to grant equal rights to the other users of the airspace. In this country we have the technology, the operational "know-how," and the manufacturing capabilities to determine the requirements, design the system, build the equipment, and place it in operation so that, when completed, it will meet the requirements of all classes of aviation operators. We have witnessed a fair degree of progress in this field, but we have not realized even a substantial part of what would have been possible had all the agencies entered wholeheartedly and honestly into a coordinated effort to arrive at the single civil/military system which is called for in our present national aviation policy. We need a truly Common System in the broadest meaning of the term, but we will never have it as long as any operating or service organization spends its time attempting to achieve its own ends regardless of the results to others.

Up to this point I have dealt with the present requirements of the Navy in its two operating environment and have set forth some of the difficulties and problems that have been encountered in attempting to satisfy the requirements. What of the future? First, let me say that any attempt to state realistic requirements for a period of 10 to 20 years in the future in fields as dynamic as air navigation, communication, and traffic control is at best only an educated guess based on the extension into the future of our progress in the past and on the knowledge that, in America, if we build a better system of any kind, it is only a short time before this system is "old hat" and new requirements then generate the need for a new system. Literally, there is no such thing as an "ultimate" system.

The Common System must be an integration of many facilities which provide navigation, communication, and control services to all users of the airspace. It must also be an information-gathering, processing, and display system to enable those persons charged with the application of control to discharge their duties with as little disruption as possible to the flow of traffic. Above all, its design must be of such nature that, in time of national emergency, it will integrate harmoniously with

the air defense system and will, in fact, become an operating part of it without the need for realignment of functions or change in command. To obtain smooth operation in time of war, the system must be designed and built in time of peace. Later on will be too late.

The statement of future system requirements that follow have resulted from serious consultation among those military and civilian personnel of the Navy who are best fitted to evaluate the long-range development and attendant logistic requirements of naval aviation and to judge the interrelated effects on and by the Navy with regard to the other operating agencies. The following operational requirements are based on the period 1965–1975:

Navigational Aids:

(1) The enroute aid must be of a type that can be installed on a single site and will provide azimuth and distance information relative thereto to a line of sight distance of between 200 and 300 nautical miles and to an altitude of at least 100,000 ft.

(2) The system accuracy must be 1 deg. and, preferably, 1/2 deg. in azimuth. The distance accuracy must be at least 2/10 of 1 per cent of the measured distance and preferably, 1/10 of 1 per cent.

(3) It must be practicable to set up quickly the en route aid, without extensive site preparation, to meet our air navigation requirements in amphibious warfare. When so installed, it must operate satisfactorily and provide azimuth and distance information to the required degree of accuracy.

(4) It must operate satisfactorily when installed on ships of the fleet.

(5) It must meet the requirements of the civil users of the airspace.

(6) It must be realized that the high order of accuracy stated is a military tactical requirement. It is probable that it may be successively relaxed in various types of civil operations. Therefore, the air-borne component design must be of such nature that cheaper, lighter, and smaller units may be manufactured to assure equipment in the price ranges required to meet the needs of all categories of operators.

(7) A single "black box" should be capable of providing for the pilot all visual guidance required for en route, terminal, and landing operations, and it should also be capable of providing electrical inputs for an automatic pilot.

(8) System design should envision the later introduction of improvements and should provide these improvements by a modification or replacement of the single box rather than by a continuing installation of additional boxes in the aircraft.

(9) The burden of equipment weight, space, and complexity must be on the surface equipment rather than in the air frame.

(10) To permit complete freedom of choice of routes, the aircraft must be equipped with a navigation computer suitable to provide visual information to the pilot or electrical inputs to an automatic pilot. In effect, this requirement spells out the need for navigational aid coverage on an area basis instead of, or in addition to, the existing route implementation.

Communication Facilities:

(1) In consonance with joint military planning, the Navy's tactical communications are being conducted in the ultra high frequency band. Therefore, it is required that the Common System be implemented with ultra high frequency transmitters and receivers in the quantities and at the locations found necessary. This is required to prevent hindrance to naval aircraft movements due to inadequate communication facilities. Although the Navy has requirements for other types of communication, voice radio will be required for the foreseeable future. This Navy requirement should not be interpreted to mean that all Common System voice communications should be conducted in the ultra high frequency band.

(2) The Navy has an urgent requirement for automatic data transmission. This requirement is both tactical and logistical in nature. In each case, it is based on the need for faster exchange of data than is possible with voice radio, for visual display of information instead of aural reception, and for use of a few instead of many frequency channels. There has been a general acceptance of this requirement for the Common System, but, with the exception of the present Navy and Air Force developments in this field, very little has been done toward accomplishing the desired result. This system will be one of the most difficult to design and install and will require a long period of time to become operational. An immediate attack should be made on this problem.

(3) The exchange of information between various positions on the ground is more complex than the communication of information between pilot and controller. In a dynamic traffic system, there is a constantly changing requirement for basic communications and internal communications dispatching. Soon there will be a requirement for the distribution of this information to a number of control computers. The human voice does not lend itself to this type of operation so that automatic means of transmitting, receiving, and display and computer insertion will be required simultaneously. It is probable that both digital and analog techniques will be used.

(4) Except for differences in frequency bands, numbers of channels, and power used, there has been no basic change in our aeronautical communications methods in the last 30 years. Although we know that there is a need in both the military and Common System for automatic data links, we are not entirely sure of how they will be organized and used or of the requirements for interconnecting services. The communications service is the one service that holds together and makes possible any form of air traffic control—either military or civil. Thus there is an urgent requirement for the establishment of a group to study the future requirements for military and civil automatic communications

from a systems as well as an equipment standpoint. The establishment of such a group is long overdue.

Traffic Control:

(1) The air traffic control system must be designed to integrate with the air defense system. This is mandatory and vitally affects the defense of the country.

(2) Where possible of accomplishment, single facilities, operating space, communications installations, etc., should serve for both air defense and air traffic control. This is necessary in the conservation of available frequencies, equipment, and the manpower required for operating and maintaining the facilities. Another result of dual purpose facilities is a direct saving in money due to the elimination of duplicatory facilities and their logistic support.

(3) The system must provide the maximum degree of flexibility. The present inflexible route system on which control is exercised on a step-by-step basis, both vertically and horizontally, is too susceptible to stoppage. Once stopped at a single point, the effect quickly spreads to departures scheduled to take place from airports many hundreds of miles distant. This system must give way to one of greater fluidity so that, if a stoppage develops, the system will have the capability of routing traffic around that area without loss in capacity or safety.

(4) There must be a high capacity identification system capable of meeting the identification requirements of traffic control as well as those connected with national defense. This system must be capable of indicating aircraft category and individual identity within each category.

(5) One of the weakest links in our present system is our inability to communicate with sufficient speed between all individuals—both on the ground and in the air—who must take part in the function of traffic control. Present manual voice transmission is so slow and unsatisfactory that an inordinately large number of communication channels, each with its operator, is required for the exchange of information required for the implementation of traffic control functions. As mentioned before, there is an urgent requirement for the development of a high-speed data link for the purpose of handling the large amount of message and control traffic on a discrete address basis.

(6) There is a decided limit to the amount of movement information that a human controller can handle solely with his own mental equipment. As the number and speed of aircraft, the number of airports in the area, or the complexity of the traffic patterns increase, the human controller quickly reaches the limits of his capabilities to keep aircraft safely separated. The present cure for this condition is to decrease the size of the control sectors so that each controller will keep within his capability. This in turn gives rise to an increasing requirement for more sectors, sector controllers, and coordination between them. Thus, as more personnel are added, the requirement for coordination becomes greater and the output per person becomes less. We have about reached the practical limit of this type of system. To be satisfactory, a future system will need traffic control computers which are capable of accepting vital position, velocity, and destination information on all aircraft in a given area and which automatically compute optimum safe tracks and provide the pilots with the guidance required for the safe and expeditious completion of their flights. Inputs to such a computer can be provided from ground-derived radar information or from automatic position reporting by the aircraft or from both.

(7) The computers mentioned above will be mandatory in our future system, but, long before we have that system, we must greatly improve our present methods of displaying information. The existing system of strip posting contains the essential information required for the exercise of control—but in such form as to make it most difficult and slow to analyze. We, therefore, need a pictorial type of information display, so designed that the area under control, the traffic therein, and its identification are all shown in proper physical relation to each other.

(8) In order to provide the utmost of flexibility in system implementation, the matter of evaluation, from interim to future system, must be carefully worked out. System design must provide for the expansion or contraction necessary to meet changing traffic requirements on a long-term basis without making obsolete the equipment already installed.

(9) In the immediate future, the use of medium and long-range radar and its supporting facilities, such as the safety beacon, must be greatly expanded in both location and operating radius. Properly designed, installed, and used, it presents a tried and proved means of expediting traffic flow into and out of our major terminals.

Before concluding this presentation, I would like to make a few remarks concerning certain developments which have, at times, been mentioned as having application to the air traffic control system. These are VOLSCAN and SAGE. Each of these developments was aimed at the solution of a specific problem. VOLSCAN, basically a series of input equipments, computers, error signal, and command generating equipment, requires a radar to supply position information on the aircraft under control and a communication circuit to the aircraft for the transmission of command data. VOLSCAN was designed for the sole purpose of providing the automatic computation required in the "return to base" problem and provides a means of controlling arrivals to an approach "gate" to a very close time tolerance. VOLSCAN has proved that it can fulfill the purpose for which it was intended. A large traffic flow is a highly desirable result in any traffic control system, but, in the Common System, safety must be maintained above all else. In the case of VOLSCAN, safety is a by-product of scheduling the

(*Continued on page 101*)

The hidden effects on overall aircraft performance of adding "another black box."

The Impact of Electronic Equipment on Electric Generator Design and Aircraft Power Plants

Henry Rempt* and M. J. Cronin*
Lockheed Aircraft Corporation

Introduction

"Let's add another black box." This seems to be the cure-all of today's air-borne system. If you are troubled with "incompatibility" or your system is not responding properly, or if you are experiencing system sluggishness, the doctor will recommend adding another black box! (I use the word "doctor" advisedly.) We have many doctors in our business these days, and they are needed!

If we are at the point of "adding another black box," what does this mean? To the aircraft designer, it usually means space, weight, and accessibility. In this discussion I should like to point out some of the hidden effects of adding a black box, particularly with respect to the aircraft generating system and the power plants.

It might well be said that up until 10 years ago the power-plant engineer was a master in his own right, and no one challenged his reasoning that the main purpose of an engine or power plant in an airplane was to propel the airplane through the air. In fact, there are those who take this stand today and have the attitude that, if the accessory systems engineers need any special or large amounts of power, they should provide it themselves. "The tail is wagging the dog" is a common expression of such feelings, but fortunately it is now realized by most engineers that the power-plant, air-frame, and accessory systems are, and must be, an integrated design effort if the aircraft performance and mission are to be optimized. We might therefore modify the above quote by saying that we are now at least at the happy stage where we are not quite sure "who is wagging whom" or "which is wagging what."

Fig. 1 shows a comparison of equipment cost, equipment weight, and man-hours for electronic system installations at Lockheed aircraft during the last three 5-year periods. Fig. 2 clearly shows the "outward effects" on an aircraft of today's greatly enlarged electronic systems.

Presented at the Electronics Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

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Electronic Power Requirements

The power requirements for electronic equipment have always been somewhat special, and, even prior to World War II, it was necessary to provide a separate high-voltage supply for the plate circuits of the radio receiver/transmitter sets, etc. The usual method of doing this was to install rotary converters, sometimes called genemotors or motor-generators. These operated from the aircraft's 12- or 24-volt d.c. system and provided an output on the order of 100 or 300 m.a. at a direct current voltage of 100–250. In later aircraft, these d.c. converters were gradually replaced by inverters, which were also motor-generator sets operating from the aircraft's low-voltage system, except that the output was alternating current generated at a frequency of 400 cycles per sec. and a voltage of 115. The electronic equipment then contained its own power supply conversion equipment to provide the necessary d.c. power and filament voltages.

Fig. 3 shows a typical inverter and its associated control box.

To understand this change to a.c. power, it would perhaps be well to review some of the advantages which led to this choice:

(1) A single a.c. voltage source could be transformed to any other voltage to suit the particular demands of equipment, and it enabled more than two different voltages to be used within a single set.

(2) By the use of transformers and metal rectifiers, the a.c. power could be rectified to provide (statically) any value of d.c. voltage required.

(3) Advantage could be taken of the many references inherent in a.c., such as the effects of change in capacitance, power factor, frequency, resonance, etc., as intelligence sources.

(4) Circuits could be used in electronic equipments, which depended upon phase comparison or phase shift, etc.

(5) A.C. power permitted the use of brushless-type transmitters and position indicators and at the same time made available a larger number of a.c. instruments,

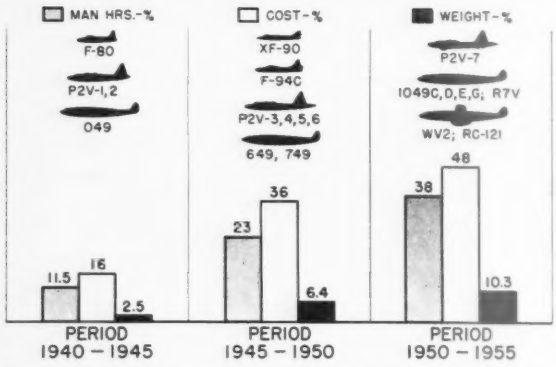

FIG. 1. Electronic system growth; man-hours, cost, and weight.

FIG. 2. Lockheed WV2 showing radomes.

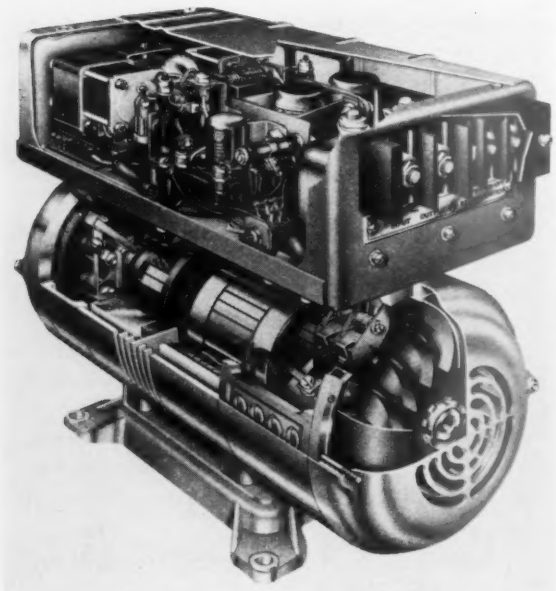

FIG. 3. Cutaway view of Jack & Heintz 2,500 VA inverter; weight, 63 lbs.

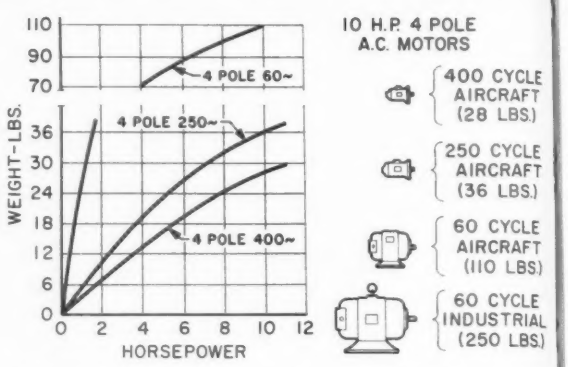

FIG. 4. Weight vs. frequency of 400-, 250-, and 60-cycle a.c motors.

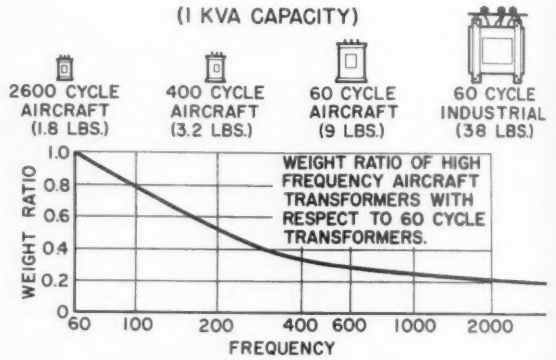

FIG. 5. Weight vs. frequency of 2,000-, 400-, and 60-cycle transformers.

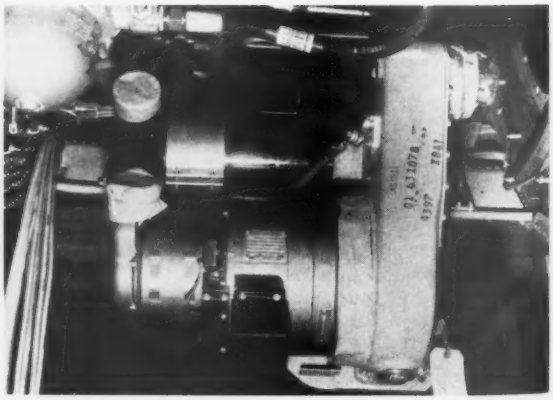

FIG. 6. Accessory box shown in lowered position (in WV2 airplane).

motors, and devices whose operation and reliability were far superior to their d.c. equivalents.

The foregoing summarizes some of the advantages of a.c. power, but they are exclusive of those which accrue to the electric system as a whole.

The Choice of Voltage and Frequency

Although the decision to use an operating voltage of 115 volts to ground was quite readily agreed upon, the choice of the frequency of 400 cycles per sec. was not so easily established. There was no doubt that a frequency higher than 60 cycles per sec. was necessary in order to achieve the desired weight reductions, and the proposed and discussed values ranged from 250–2,400 cycles per sec. We might therefore review some of the factors which dictated a choice of a higher frequency:

(1) Transformers, motors, and other electromagnetic equipment weights could be minimized since the magnetic iron required decreases as the frequency increases.
(2) A.C. motors could be operated at higher speeds—which decreases their weight for a given hp. output.
(3) The weight and size of inductors and capacitors were decreased at higher frequencies.
(4) The size of filter components for electronic equipment were reduced.

The advantages of high-frequency operation and an appreciation of the relative sizes of components at high and low frequencies can be obtained from Figs. 4 and 5.

To appreciate why the weights of motors and transformers are affected by frequency, we might consider the following. For a given applied voltage, the flux—or field strength—required in a motor or transformer decreases as the frequency is increased. This means less iron. In the case of a.c. motors, speed is directly proportional to the frequency, and high speeds can be achieved if a high frequency and small number of poles are used. Thus, for a given hp. output, the torque is decreased by the high speed and so weight is reduced.

It might appear from this that it would have been better to have used as high a frequency as possible and that 2,000 cycles per sec. would have been a better choice than 400 cycles per sec. This reasoning, unfortunately, overlooks the fact that eddy current and hysteresis losses increase as a function of frequency so that a point of diminishing returns is reached. Furthermore, while 2,000 cycles per sec. might have been a better choice for electronics equipment, it would have resulted in serious compromises with other electrical equipment. Motors, for instance, would have to be wound with a large number of poles in order to bring their speed down to usable limits, and this would have resulted in an uneconomic design in both winding space and iron circuit. As an example, to obtain a speed of 8,000 r.p.m. on 2,000 cycles supply it would be necessary to wind the motor with 30 poles.

The frequency of 400 cycles was therefore considered a good compromise since it allowed sufficiently high speeds for a.c. motors and, at the same time, went a long way toward meeting the requirements of electronic equipment. Motor speeds of 24,000 r.p.m. could be achieved with 2-pole winding designs, and, although still too high for most applications, it is used in certain gyro instruments and navigational aids, where high angular momentum is required. The increasing use of axial compressors and turbines also raises the requirements for high-speed a.c. motors, and it is likely that we shall see a greater application in this field in the near future.

The Effect on the Electric Generating System

The pattern for a.c. power and its frequency having been so established, the impact on the airplane's main electric system could now be traced through the various phases.

While converters and inverters fulfilled the intermediate needs of the electronic equipment, it soon became evident that they could no longer supply the growing demands for electronic power. In Navy patrol aircraft, such as the P2-V, and in the early warning radar aircraft, such as the WV-2s and RC-121Ds, six or more 2,500-va. inverters would have been necessary to meet the current or immediately foreseeable demands of the electric and electronic equipment. Since the weight of a 2,500-va. inverter installation amounts to approximately 100 lbs., it could be understood that the use of engine-driven a.c. generators became necessary as the first step toward meeting these large power requirements.

In the case of the AEW aircraft, the total electronic load amounted to approximately 14.5 kw. of d.c. power and approximately 25 kva. of a.c. power. One single equipment—the radar—alone has a power consumption of 1 kw. d.c. and 7.5 kva. a.c. Therefore, to supply this power, these aircraft had to be equipped with two 30-kva., three-phase, 400–800 cycles per sec. generators. (See Fig. 6.) Fig. 7 shows the engine accessory installation for an F-94C interceptor: one 10-kw. d.c. generator, one 8-kva. a.c. alternator for electronics, and one 30-kva. a.c. alternator for deicing.

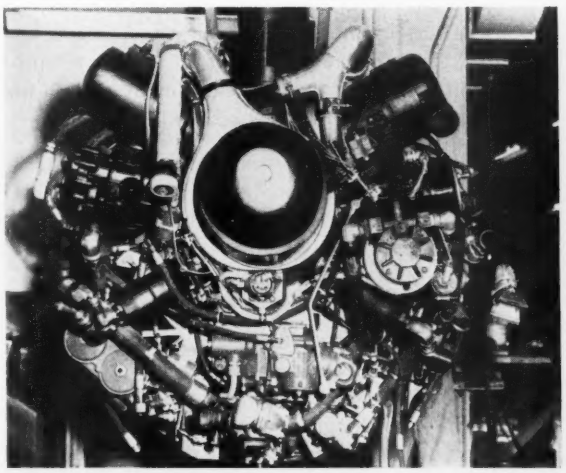

FIG. 7. View of engine accessories in F-94C airplane.

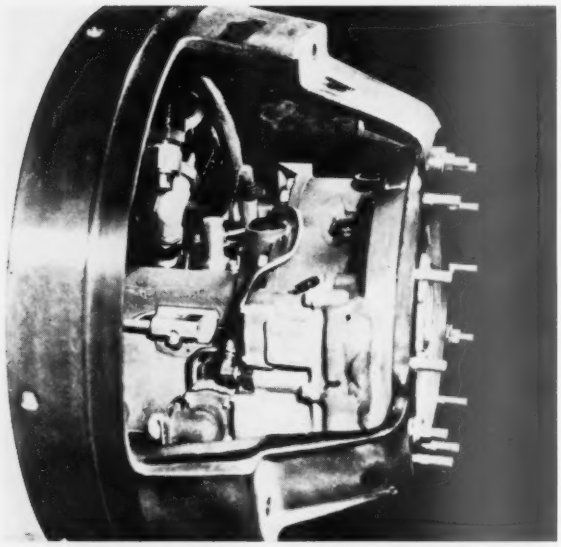

FIG. 8. Nose cone installation of Sunstrand constant speed drive.

At the many national and international meetings held to discuss the future aircraft electric systems, a three-phase supply was adopted as the one offering the most flexibility and adaptability to all the varied requirements of a large electric installation.

It was foreseen, for instance, that there would be demands for large a.c. motors, and these would be far better suited to three-phase operation in view of their smoother torque characteristics, higher efficiency, and lower weight. At the same time, three-phase motors rendered special starting devices unnecessary, and, by connecting the neutral point of the generators and motors to ground, two-phase starting was possible even with a ground or open circuit on any one of the three motor leads. Another advantage of grounding the generator neutral was that it provided two voltages, 115 and 200 volts, so that electronic equipment could be either three-phase power at 200 volts or single-phase power at 115 volts.

As to the frequency range, this is something that is dependent on the speed at which the generator is driven. Thus, in the case of a direct engine-driven generator, the frequency of the supply is in direct proportion to the speed of the engine driving it, and, in the case of the AEW aircraft, this resulted in a frequency range of 400–800 cycles.

MAIN ENGINE DRIVES AND REMOTE ACCESSORY DRIVES

Piston Engines

On most early and current engines, mechanical power for the electric generators is provided by 5-in. AND 20002 pads having a nominal drive speed of 6,000 r.p.m. These pads were designed primarily for 28-volt d.c. generators so that the first impact that the growth of the electric/electronic system had on the engine was to cause a demand for bigger pads (10-in. AND 20006) capable of greater driving torques and of taking the overhung weight of large a.c. generators. Pending the provision of these pads, however, it was necessary for the aircraft manufacturer to meet the immediate requirements for a.c. power with gearboxes of the special remotely driven type—as in the case of the WV-2 and P2-V types of aircraft.

In the future, 10-in. pads will be provided on the engines, and the drives will be stressed for a.c. generator ratings up to 120-kva. capacity. These drives will, at the same time, meet the overload torque requirements of specification MIL-E-7894 which calls for generator overload ratings of 150 per cent for 5 min. and 200 per cent for 5 sec.

In terms of frequency, the piston engine is not the best choice of prime mover in view of its wide speed range (approximately 920–3,000 r.p.m.). A.C. generators connected directly to this type of engine would therefore have a frequency range of approximately 3.1, unless constant speed drives were interposed between the generators and the engine pads.

The constant speed drive is a hydraulic-mechanical variable speed transmission which compensates for the engine's speed changes and so keeps the output frequency of the generator constant. At this stage, most drives of this type either:

(1) Sandwich between the engine and the generator.
(2) Form a separate drive/generator package, connected by hydraulic lines to an engine-mounted pump or by a shaft to the engine pad.
(3) Integrate into an engine gearcase in the form of a cartridge.

Fig. 8 shows a constant speed drive installation in the nose cone of a turbojet engine.

It is thought by some aircraft systems designers that a constant speed drive, if required, is the engine manufacturer's responsibility and that it should be engineered into the power plant.

Turboprop Engines

At the outset, it can be said that the advent of the turbine engine has at least improved the speed range over which generators and accessory equipment have to

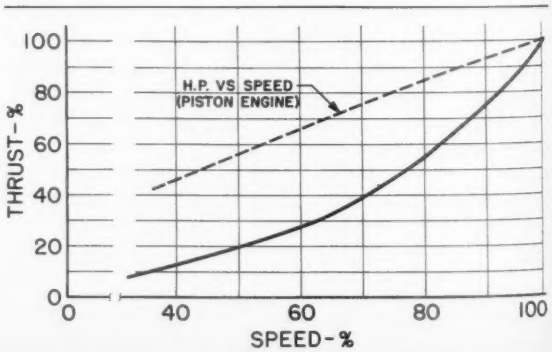

FIG. 9. Typical power vs. speed of turbojet engine.

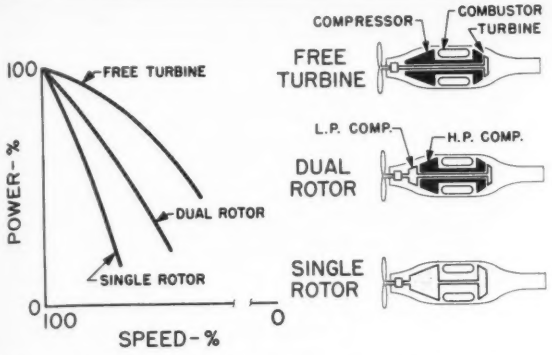

FIG. 10. Effect of speed reduction on the power output of turbine engines.

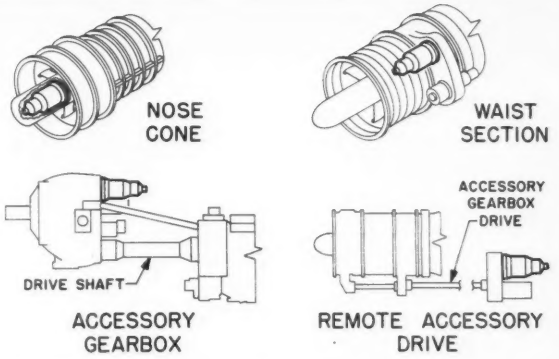

FIG. 11. Typical accessory drive provisions in turbojet and turboprop aircraft.

operate. This is particularly true under most flight operating conditions, since large power changes can be effected with comparatively small changes of engine r.p.m. (See Fig. 9.)

In the case of the turboprop engine, the situation can be even better from a speed standpoint, since it can be operated as a variable-torque/constant speed engine by using a governor to vary the pitch of the propeller as the turbine input power is varied. A typical engine power control of this type is one that schedules turbine inlet temperature as a function of throttle lever position. Thus, when a higher temperature setting is selected, increasing the fuel flow and the gas energy into the turbine, the extra power of the engines is absorbed by increasing the propeller pitch, while the engine speed is held at a constant r.p.m.

Should too much optimism be drawn from this method of control, it should be remembered that this type of operation is applicable to a particular kind of turboprop engine, and, even in this case, it may be necessary to reduce the engine speed during ground running and taxiing in order to minimize the propeller and engine noise. A total speed range of approximately 55–110 per cent may therefore exist in turboprop types of installation.

The engine just referred to is a "single spool" design, but other types of turboprop engines may be categorized as the "free-turbine" and "twin-spool" types. Fig. 10 shows diagrammatically these three types of turbine engine.

From the standpoint of operating speed range, both the free-turbine and two-spool engines can be operated successfully over a wide speed range without running into surge or compressor stall problems. In relative terms, the single-spool engine is much more sensitive to changes in speed and its power falls off more rapidly, with decrease in speed, than does the free-turbine. In both engines, however, for reasons of efficiency and specific fuel consumption, it is likely that the operating speed range in flight will still be quite narrow, since, unlike the piston engine, turboprop engines can cruise continuously at speeds of 90–94 per cent of maximum.

It will be seen from the foregoing that insofar as electric generation is concerned on turboprop engines, a typical flight frequency range could be 380–420 cycles per sec. if 100 per cent generator speed (400 cycles per sec.) were made to correspond to 95 per cent of engine speed.

With regard to generator installations themselves, there are four basic configurations for turboprop and turbojet aircraft: nose cone, accessory gearbox, waist section, and remote accessory gearbox. Schematics of these arrangements are shown in Fig. 11.

Turbojet Engines

The operation of the turbojet engine insofar as it affects the operation of accessory equipment differs little from that of the turboprop engines, since the fundamental power vs. speed relationship still applies and the high slope of this curve permits operation of the airplane over a wide range of conditions with relatively little change of engine speed. Also, like the turboprop engine, consideration of the optimum compressor and turbine efficiencies will probably dictate the operation of the engine at a relatively constant speed. As before, typical cruise engine speeds would be 90–94 per cent.

One point that has not been given sufficient attention in most aircraft up to now has been the impact of the accessory power extraction on the performance of the engines. The danger of this has now been seen, however, and air-frame manufacturers are now asked by their customers to present the power-plant performance with the appropriate thrust or shaft hp. corrections made for accessory power extraction. That such corrections are important can be appreciated from the fact that, where the electric power in our largest World War II aircraft was supplied by four 6-kw. generators, requiring only 40 hp. total or so, four 60- or 90-kva. a.c. generators will not be uncommon in current civil and military airplanes. The engine power requirements for these systems alone would amount to 360–540 hp., and a total of 1,000 hp. for all accessories probably, would be stating the case lightly.

As to the effect of these power extractions on the engine, two main factors should be considered: the increase in fuel consumption required by the accessories and the effect on the thrust or performance of the en-

gine. In the former case, the figure depends largely upon the efficiency of the shaft hp. production at the accessory drive pad, although this is not necessarily a simple case of working out the overall mechanical efficiencies. A more accurate way would be to measure the fuel consumption without accessory power extraction and then again with power extraction. This would then take into account any change in the operating efficiency point of the engine and would be one figure of merit.

Another way—and this would take in the overall effect—would be to measure the increase in horsepower or thrust, which would be obtained if the amount of fuel required by the accessories were applied to the engine only (without the accessory power extraction). This figure would then give a value of the horsepower or pounds thrust penalty on the engine for every hp. of accessory power extraction. Since this figure would not be a constant and would vary with different engine power settings, it would be necessary to evaluate this relationship over all the applicable range of engine settings as they obtain at the various flight speeds. It is therefore not easy to establish one figure of merit, and it is a subject on which it is dangerous to generalize.

As an example of the amount of fuel required by a large electric/electronic system, we might consider the case of a turboprop or turbojet airplane having a flight time of 8 hours. Assuming a direct-driven generator installation of 400-hp. capacity with an efficiency of 85 per cent and a fuel consumption of 1.3 lbs./hp.-hr. (for the production of this power at the shaft), the total weight of fuel required would be approximately 4,150 lbs. or roughly 700 gal. If a constant speed drive of approximately 80 per cent efficiency were used with the generators, then this value would increase to 5,200 lbs. or 870 gal.; a different value would apply if remotely driven generators were used.

This method of assessing the fuel consumption does not, of course, take cognizance of any reduction in performance of the engines as a result of accessory power extraction. It might therefore be said that, if the flight time of the airplane has been increased on this account, then the extra fuel consumed by the engines during this period is also attributable to the accessory system.

The moral of all this is that the electric/electronic equipment has pronounced effects on the airplane's engine and fuel systems, so that the methods by which the power is generated are extremely important for long-range aircraft if large fuel weight penalties are to be avoided. In order to obtain the highest efficiency, the drive sources should be as direct and simple as possible.

Remote Accessory Drives

So far only engine-mounted generators have been considered, but there is a rising interest in the application of remote accessory drives which stems from these three basic considerations:

(1) Insufficient power from the engine-driven pads.

(2) The number of pads or drives on the engines may be limited or restricted.

(3) The increase in nacelle size to accommodate accessory equipment may impose high drag penalties on the airplane.

Here again, in making observations on the application of remote drives, it is unwise to generalize since there is a time when the best judgment or views may be overruled if there are definite practical limitations to them. More specifically, air turbine motor drives, for instance, may not be the best choice from an overall performance and efficiency point of view, but they may be the only practical solution if mechanical drives are not available or space limitations on the engine militate against the use of engine-mounted generators.

In considering remote drives, we are concerned mainly with air turbine motors (ATM), both direct bleed and bleed-and-burn types; gas-turbine power units (GTPU); and hydraulic motor drives.

Air Turbine Motors

There are those who hold the view that a complete air system is a panacea for aircraft accessory power, and, it is, in fact, true that any single integration of all aircraft equipment for operation from one common power source results in favorable evaluation of the system. However, there are factors concerning the use of ATM's which should be investigated where there is a choice between these and, say, direct engine-mounted generators.

The first pertinent factor in connection with air drives is the overall efficiency of this method of extracting mechanical hp. from the engine. This evaluation must, as in the case of the direct drive, be evaluated in relation to the change in the engine's specific fuel consumption and the effect of the bleed on the engine and air-frame performance. One thing seems certain: Direct bleed air compares unfavorably with direct engine drives in this respect—a figure of 1.4:1 has been quoted. Also, depending on the type of engine power control system will be the amount by which the engine performance is affected. In the case where turbine inlet air temperature is controlled as a function of power lever setting, increasing compressor bleed would result in a fuel reduction, thus reducing engine power. In the cruise regime, this may be avoided by increasing the engine power setting in order to restore the status quo, but it would not be possible in the takeoff configuration where the engine would already be operating near or at its maximum temperature limits. The accessory power extraction, therefore, has a direct impact on the airplane's take-off performance; while, in the cruise regime, the increase in fuel consumption, necessary to restore the engine's performance after accessory power is extracted, is a direct weight penalty against this type of accessory power system.

Other factors that can be reviewed are those that relate directly to the air turbine itself. One of the fundamental difficulties is to design the turbine to operate

efficiently over the wide range of bleed air conditions—from ground to maximum cruise altitude and back again to idle descent let-down. In the first and last cases, a condition of low adiabatic head exists, and large volumetric flows are required to maintain output power. In fact, in any air turbine installation, one of the most important factors would be to analyze and establish accurately all the changes in the energy of the bleed air and duct losses under all the varying flight conditions and changes in air utilization. It is, of course, possible to design the turbine wheel speed to meet the worst bleed conditions, but then excessive losses are inherent during continuous cruise conditions. Another approach would be to use a variable area nozzle design, but here again the overall operating efficiency is being compromised rather than optimized.

On the credit side of the ledger, air turbines have the following advantages:

(1) They can be installed at or near the main electric distribution center and so save the weight of long power supply cables—necessary in the case of wing mounted generators.

(2) They permit full output power even though a single engine is dead since input air supply manifolding provides diversity of air supply.

(3) They permit paralleling of the generators if required, and, if a ground source of air is available, electric power can be obtained without running engines.

It will be seen from the foregoing that one of the main disadvantages of direct bleed air turbines is the efficiency of the power extraction from a fuel consumption standpoint. One of the methods of overcoming this deficiency is to use bleed-and-burn air turbines.

Bleed-and-burn air turbines have the basic advantage that their efficiency is superior to that of the air turbine motor, and, in terms of specific fuel consumption, they are claimed to be as efficient as the direct method of hp. extraction. Bleed-and-burn turbines would therefore be more economical for a long-period flight, where there would be relatively large fuel savings over a straight air turbine installation. On the other hand, the bleed-and-burn system is not such a facile installation as the air bleed installation, and it is faced with a bigger potential fire hazard. The extra safety precautions thus required, together with the piping of fuel to parts of the airplane (not otherwise necessary) and the additional control problems, all tend to detract from the initial advantage of this type of installation.

Gas-Turbine Power Units

There is a growing demand in some large aircraft—particularly military—for self sufficiency of the airplane in respect to its accessory installation, and the gas-turbine power unit goes a long way in fulfilling this need. (See Fig. 12.) Another solution is to install a gas-turbine compressor (GTC) in the aircraft whose sole function is to provide air, which is then used to heat and pressurize the cabin as well as to drive various accessory ATM's during ground and/or flight operation. This then may be a case where the effect on the main propulsion engine is nil. However, complete special engine installations are required just for the accessories.

FIG. 12. Solar Aircraft Co. gas-turbine auxiliary power unit as used in Lockheed R7V1 airplane.

One thing is certain: The requirements for bleed air for boundary-layer control and deicing purposes are already so demanding that they tend to strengthen the case for self-contained accessory power systems. From an aesthetic standpoint, it is a system which would be welcomed by electronics/electrical engineers who have been indoctrinated in industrial philosophies. Nevertheless, there are a number of practical difficulties: The first main factor is that the GTC and the GTPU must be treated in the same way as the main power plant to the extent that it may be necessary to consider their mounting on the wings along with the main engines. An evaluation of the drag, structural, and other penalties must therefore be made for this type of installation.

If the units are mounted at discrete points in the fuselage, then their enclosure in fireproof containers, together with other fire preventive measures, is necessary; it would also be incumbent on the engineer to ensure containment of all mechanical parts, such as the turbine buckets, in the event of any structural failure of the turbine itself. Added to these considerations is the more "mundane" consideration of weight which can be said to be fourfold.

(1) There is the dry weight of the installation, which includes all the structural provisions for the units, piping, tankage, and control.

(2) There is the question of specific fuel consumption where the basic consideration is how the overall efficiency of the unit compares with the main engine. It should also be remembered that the units, designed for flight use, must operate over all the same altitude/temperature conditions as the main engines and must have capacity to meet the 200 per cent load requirement over the complete flight range.

(3) Because of the possibility of GTPU or GTC failure, a dual installation is required.

(*Continued on page 125*)

A description of the design and performance of an EGTI system developed to meet demands for increased accuracies.

A Precision Servo-Type Thermocouple Temperature Indicating System

G. H. Cole*
Minneapolis-Honeywell Regulator Company

MANY OF TODAY'S jet engines are operated at as high an exhaust gas temperature as is commensurable with reasonable engine life in order to obtain maximum possible performance. Thus, because of the close relationship between exhaust gas temperatures and engine life and performance, the need for precise temperature measurement has become critical in recent years. Where formerly temperature indicators with accuracies of 3 per cent were believed sufficient, it is now desirable to obtain in the order of ±0.5 per cent measurement accuracy. The latter accuracy approaches that obtainable only with laboratory-type instruments and standards.

To illustrate the effect of temperature upon the life of a typical engine, an increase of 10°C. in sustained temperature above a certain limit may result in a reduction in engine life of about 120 hours. On the other hand, if the maximum permissible temperature is not maintained, sacrifices in performance will result. Experience has shown that, in the case of one aircraft, an additional $1^1/_2$ per cent of runway length is required for each 10°C. increment below a maximum permissible temperature.

The design and performance of any temperature indication system is closely tied to the sensor characteristics. Thus, it is interesting to examine the stringent requirements for exhaust temperature sensors. These requirements have dictated the use of thermocouples almost exclusively.

Temperatures in the exhaust area range from −65°F. (representative of a cold day on the ground with the engine unlit) to 1,800°F. (with the engine lit). Thus, the sensor must withstand extreme thermal shock and long periods of constant high temperature. The sensor is subjected to gas velocities in the order of 1,800 ft. per sec. Small particles of dirt or dust and larger pieces of scale impose severe abrasion conditions on the sensor at this velocity. The surrounding atmosphere may be highly oxidizing or reducing and may contain salt spray or unburned fuel. The sensor must have sufficient strength and chemical resistance to withstand these conditions and yet must be small enough to give a fast response to temperature changes.

Because of their adaptability to the above conditions, Chromel-Alumel thermocouples have been used almost exclusively as jet exhaust gas temperature sensors. Resistance thermometers, when designed for fast response, have proved to be fragile and costly to fabricate. Thermistors, although exhibiting good mechanical possibilities, have not as yet proved to be stable at the higher temperatures. The Chromel-Alumel thermocouples possess good corrosion resistance, mechanical strength, and relatively high output signal. (We say relatively high because, unfortunately, even the better thermocouple combinations yield a relatively low-level signal when compared with other sensor outputs. The output signal of the Chromel-Alumel thermocouple per degree centigrade is about 40 microvolts d.c.)

An average temperature indication from around the jet exhaust periphery is usually desired. Thus, multiple couples are usually equally spaced around the exhaust area and are connected in parallel to yield an average reading.

D'Arsonval Type of Indicator

Until now, the device commonly used to indicate the thermocouple output has been designed around the D'Arsonval galvanometer movement. Here a coil of wire is suspended in a magnetic field—usually produced by a permanent magnet. When a current is established in the wire, a force is exerted on the wire to deflect it from its position of rest. Its de-energized position is usually determined by a light spring attached to the wire. The resulting deflection of the wire against the spring is then used as an indication of the magnitude of the current by means of an attached pointer.

The basic disadvantage of this system is that it draws current from the thermocouple during indication. As the available thermocouple power is very low, a small lead resistance can cause an appreciable voltage drop which reduces the current through the D'Arsonval

Presented at the Instruments Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Design Engineer, General Instruments.

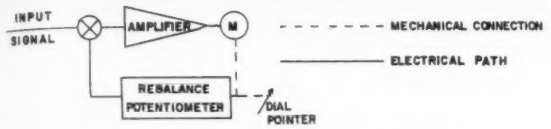

FIG. 1. Basic servo null-balancing system.

movement. For this reason, large gauge thermocouple wires are used to reduce resistance. To assure that each indicator is affected equally by external resistance, a trimming resistor is provided to adjust the external resistance to a predetermined value. However, this measure does not protect against lead resistance variation with temperature, and trimmer readjustments must be made when the installation is changed.

As with all thermocouple systems, the effect of the thermocouple cold junction must be considered. Cold junction compensation of D'Arsonval-type indicators can be accomplished by mechanically biasing the spring by any one of several means. Temperature-sensitive resistors inside the indicator are commonly used to compensate for temperature effects on the coil-wire resistance. With precise lead calibration, typical accuracies are in the order of ±1 per cent to ±3 per cent at room temperature and ±3 per cent to ±5 per cent under environmental extremes.

There are other inherent disadvantages of the D'Arsonval-type indicator which result mostly from the lack of available driving power. It requires fine bearings and springs which subject the indicator to possibility of damage from mechanical shock. As the wire coil nears its maximum deflection, the nonlinearity of the spring loading becomes apparent as the coil movement per unit change in current becomes less. This, of course, is reflected in the dial calibration and results in a nonlinear scale which becomes compressed at the higher temperatures.

It is apparent that, to better the D'Arsonval-type system, much of the improvement would have to result from closer control of the leads themselves. Additional improvement in sensitivity would have to come from better (and more fragile) D'Arsonval movements which have already reached a high state of development.

With the characteristics of jet engines and the foregoing system weaknesses in mind, the following aims were set for the development of a precision temperature indication system:

(1) The system should operate from Chromel-Alumel thermocouples.

(2) The maximum error of ±10°C. should exist under environmental extremes.

(3) The measured temperature span should be at least 800°C.

(4) The system should be insensitive to lead resistance.

(5) The system should be capable of full-scale response within 2 sec. with minimum pointer overshoot.

(6) The system should remain within calibration for at least 1,000 hours.

(7) Readability should be made maximum by means of main pointer travel in the order of 300° and the addition of a vernier dial if desired.

(8) Actuation of switches, potentiometers, or synchros for transmitting temperature signals shall be possible.

(9) The system should require 115-volt, 400-cycle power only.

(10) The system should combine minimum weight, volume, and cost.

SERVO NULL-TYPE SYSTEMS

A servo null type of system promises to solve most of the problems outlined above if suitably adaptable to aircraft environment. The inherent accuracy of this type of system is borne out by the fact that the great majority of precision laboratory and industrial instruments employ this principle in one form or another.

A simplified null-type servosystem using a potentiometer rebalancing member is shown in Fig. 1. The input signal is compared to the voltage existing at the slide of the rebalance potentiometer, and the difference or error signal is impressed upon the amplifier. The amplified signal is then impressed upon the motor which in turn positions the potentiometer slider to pick off a voltage exactly equal to the signal voltage. Once the two voltages exactly equal and cancel each other, the motor comes to a stop as the amplifier signal has been nulled. The potentiometer slider can then be used as a relative indication of the signal magnitude by means of a pointer.

Use of the null-type servosystem effectively isolates the sensor from the power required to produce indication; and the effects of friction, hysteresis, reversal loss, and rebalance member load on sensitivity are virtually eliminated. As no current is drawn from the thermocouple at null, the lead resistance has negligible effect upon calibration.

The design of a servo null-type system employing thermocouple sensors actually takes the form shown in the block diagram of Fig. 2. It can be seen that certain circuitry additions to the basic servosystem are necessitated by the use of thermocouple sensors. These are the cold junction compensation, the d.c. reference voltage, and the d.c. to a.c. converter. The following paragraphs briefly outline the function of these elements.

The reference voltage is the heart of a system such as this. It is necessary that this d.c. voltage be ex-

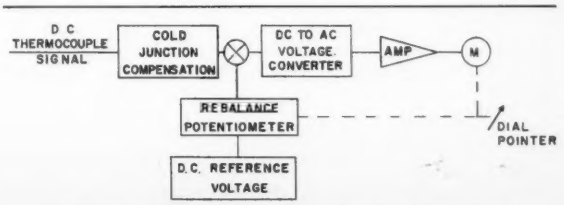

FIG. 2. Thermocouple servo null-balancing system.

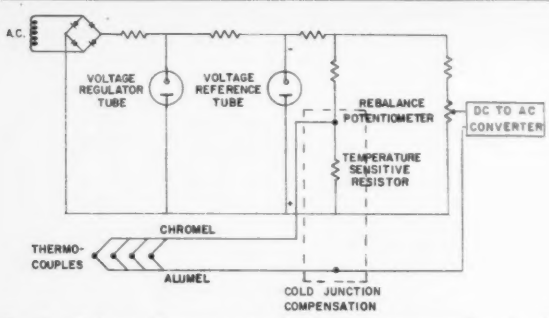

FIG. 3. Voltage reference and cold junction compensation circuit utilizing gaseous regulator and reference tubes.

ceedingly stable and repeatable as it is used on the rebalancing potentiometer to null the incoming thermocouple voltage. Its accuracy directly affects the system accuracy.

The cold junction compensation—as we have previously explained—is necessary to neutralize the d.c. voltage generated by ambient temperature at the termination of the thermocouple leads. This compensation can be obtained conveniently by drawing a constant current from the reference voltage and passing it through temperature sensitive resistors. The resistors are chosen so that the product of the current and the variable resistance exactly matches a Chromel-Alumel signal over the ambient temperature range. The resulting voltage is then used to oppose the cold junction voltage.

The d.c.-to-a.c. converter is necessary because it is difficult to amplify d.c. signals directly. When converted to a.c., the signal is readily amplified by a conventional amplifier.

These and the other circuit elements have been developed to a high level of precision and reliability in laboratory and industrial temperature measurement systems. Under normal environmental conditions, accuracies of ±0.2 per cent are obtainable over measured ranges in the order of 1,000°C. However, the highly accurate standard cell used for the reference voltage and the bulky electromechanical vibrators used for d.c.-to-a.c. conversion required replacement or redesign, and the entire system required miniaturization to become flightworthy.

Miniaturized Vacuum-Tube EGTI System

As a result of a project to produce a precision flightworthy EGTI system, a two-package system consisting of an amplifier and an indicator for panel mounting were developed. The total weight of the system is about 4.5 lbs. and volume about 110 cu.in. Power consumption is 28 watts. Under normal conditions an accuracy of ±5°C. is available, and under environmental extremes ±10°C. is available for a range of 800°C.

Reference Voltage

As previously pointed out, the reference voltage must be maintained exceedingly accurate as its accuracy directly affects that of the system. This d.c. voltage must be maintained essentially constant, despite line voltage and frequency variations of ±10 per cent and ±20 per cent, respectively.

The source of the reference voltage for this system consists of a gas-type voltage regulator tube and a gas-type voltage reference tube connected in cascade. These tubes were selected from the many available types on the basis of exhaustive tests to determine the tubes with the best combination of ruggedness and stability.

Life tests have indicated that the reference voltage will maintain its calibration within ±0.5 per cent over a period of 1,000 hours and under environmental extremes. As the voltage level of the output is higher than that needed to rebalance thermocouple signals, it is divided down to the millivoltage level by precision bridge resistors. A constant current suitable for cold junction compensation is also obtained from this source. A simplified schematic is shown in Fig. 3.

D.C.-to-A.C. Converter

A miniature electromechanical vibrator was designed for this application with special care toward low-noise-level performance. Vibrators—or choppers as they are sometimes called—are essentially single-pole, double-throw switches that are driven in synchronization with line frequency. The vibrator is used in conjunction with a transformer to form the input circuit to the amplifier as in Fig. 4.

Amplifier

The amplifier features three subminiature electron tubes as voltage amplifier stages and one miniature tube as the discriminator motor drive. An overall gain of about 200,000 is realized with small error signals.

The discriminator tube differentiates between the relative phases of amplified error signal and line voltage and drives the motor in a direction to null the system.

Particular care was taken in the design of the input circuit and early stages of the amplifier to guard against noise and a.c. pickup amplification. As a result, motor movement can be achieved with error signals as small as 40 microvolts (±1°C.).

Indicator

The indicator consists of a miniature, two-phase servomotor, 400:1 gear train, rebalance potentiometer, rate feedback potentiometer, and main and vernier pointers. The response time of the indicator is 2 sec. for the 200° to 1,000°C. range.

As the output characteristic of Chromel-Alumel thermocouples is not linear, it was necessary to characterize or shape the rebalance potentiometer resistance to match this curve. Characterization was accomplished by tapping the potentiometer at selected points and shunting these portions with fixed resistors. The

resulting resistance characteristic, consisting of straight line segments, matches the thermocouple curve to within ±2.5°C. at any point within the 800° range.

The combination of a high-gain amplifier and fast indicating response naturally caused stabilization problems. However, by coupling the second or rate feedback motor-driven potentiometer to the bridge circuit with a capacitor, a critically damped, 2-sec. response was readily obtained. A portion of the d.c. reference voltage was used to energize the rate feedback potentiometer.

Auxiliary Temperature Functions

The servomotor was designed for loads in excess of its two potentiometers to enable it to operate such auxiliary functions as switches, potentiometers, or synchros to transmit temperature signals for controls or warning.

Time-temperature integration systems are becoming increasingly valuable as an accurate means for determining jet engine overhaul periods. The Exhaust Gas Temperature Indication (EGTI) system can be used to furnish the temperature signal needed for the time-temperature recorder by addition of any one of the aforementioned signal transmitting devices.

System Errors

The overall accuracy of the system is affected by the following sources of errors: (1) reference voltage, (2) cold junction compensation, (3) rebalance potentiometer characterization, and (4) amplifier sensitivity. These errors can be classed as to the effect of measured temperature range upon their magnitude. The cold junction compensation and amplifier sensitivity represent fixed errors, and the reference voltage and potentiometer characterization errors are affected by range.

The system errors for the 800°C. range are as follows for normal and extreme environmental conditions:

	Normal Environment, °C.	Extreme Environment, °C.
Reference voltage	±0.5	±4.0
Cold junction compensation	±1.0	±2.5
Rebalance potentiometer characterization	±2.5	±2.5
Amplifier sensitivity	±1.0	±1.0
	±5.0	±10.0

The system was found to tolerate thermocouple lead resistance up to 200 ohms without effect upon calibration. As a result, it is possible to utilize small light-gauge thermocouple leads. The transformer input circuit permits either side of the thermocouple to be accidentally grounded without influencing the calibration.

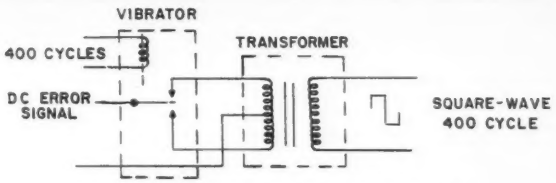

Fig. 4. Electromechanical vibrator circuit.

Further Improvements

Even before completion of the vacuum-tube system design, it became apparent that the rapid development of semiconductor devices held promise of further system improvement and miniaturization. Since that time, a development has been under way to incorporate both indicator and amplifier within a 2-in.-diameter, panel-mounted unit. This unit is now in the final stages of design. It is about $5^1/_2$ in. long which represents a volume of about 17 cu.in. Weight is about 1 lb., and the power consumption is 6 watts. The circuitry contains no vacuum- or gas-filled tubes and converts the d.c. signal to a.c. without the use of mechanical contacts. The calibration of the system should be constant over periods considerably in excess of 1,000 hours as the voltage reference means is unaffected by aging. Overall accuracy is expected to be comparable to the vacuum-tube system with distinct possibilities of betterment.

Conclusion

The design of a precision temperature measurement system as described herein has posed formidable development problems. However, once these problems were resolved, the extreme accuracy of the null-type servo principle and the convenience and simplicity of the thermocouple sensor installation were fully realized. As a result, temperature measurement accuracies approaching that of laboratory equipment have been made practical for air-borne use.

The rapid advancement of semiconductor devices has further enabled such a system to be miniaturized to the extent that the entire circuitry can be contained within the panel mounted indicator case with attendant improvement in power consumption and ruggedness.

Common System Development—1956

An exposition of the philosophies underlying the Air Navigation Development Board program.

James L. Anast*
Air Navigation Development Board

THE REORGANIZED Air Navigation Development Board has been in existence for nearly 2 years. It is reasonable and fair to ask, "What is the outlook for the Common System?"

Early in 1956, one can only answer this question with optimism. Indeed, we are approaching an era when giant strides will be made in air navigation and traffic control. There are several reasons for this:

(1) There is now an irresistible pressure from all sides on such organizations as the Air Navigation Development Board and the Civil Aeronautics Administration to deliver a system to cope with the "jet age."

(2) In spite of the almost inextricably tangled Government organization (and through "sins of the fathers"), there is a slow but accelerating progress in clarifying the system toward which we are evolving—and how we are getting to it from today.

(3) Fortunately, and apparently contrary to general thought on this subject from SC-31 onward, we do not need the invention of a new system. I take into account all the bright new systems that were proposed in the optimistic period from 1945 to 1950. They all have had their day and have been discarded.

As a matter of fact, we already possess a system of air navigation and traffic control. We need not tinker with the philosophies governing safety of operation. These have been built up by the CAA over years of careful cut and try processes. Nor do we need additional academic theories on ideal techniques for the control of aircraft. What we need is improvement in almost all facets of the present system. We need, for example, a communications system whose longest time lag is not critical to the control loop from the ground to the aircraft and back to the ground. We need higher precision in our navigation system in order that the "vanishing airspace" is not used so extravagantly. We need to relieve human controls of routine functions wherever this can be done safely and put them in machines, which are better than humans in relatively simple repetitive operations.

(4) We in the Government are finally orienting our thinking to the system problem, rather than the equipment problem. Traditionally, the system of air navigation and air traffic control has consisted of several carefully separated elements—regulations, procedures, and navigation aids. Initially, the navigation aids consisted of a few pieces of equipment—a communications set, a magnetic compass, a radio homing device, etc.

The equipment, procedures, and regulations which are required now are so intimately interrelated that consideration must be given to the entire system from the earliest stages of budget preparation, operational analysis, and planning, through the research and development phases including evaluation and service testing.

Until recently, the research and development of navigation and traffic control systems has been carried out piecemeal. The "system" was then put together by the CAA, the operating organization of the nav aids, and then welded into a working entity by the ingenuity of the operating people involved. This partly explains the traditional conservatism of the CAA in accepting new equipment. The introduction of new equipment piecemeal into an operating system might cause a deteriorating effect on other elements of the system, such as safety, number of communication channels, etc.

Presented at the Air Space Use Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Electronics Engineer, Chief—Systems Engineering Group.

If the *total* system is developed in an orderly manner and tested in a realistic environment, then there can be no reservations on its effect on "the rest of the system."

It should be pointed out that in air navigation and traffic control we have lagged behind in the evolution which has taken place universally throughout industry and the agencies of the Department of Defense in airframe development, weapon systems, telephone systems, etc. I am optimistic for the very reason that we are behind because we can draw on the successful experience of others engaged in the research and development of comparable systems.

(5) The last reason for predicting the success of the present configuration of the Air Navigation Development Board is that we have a formula for the development of the Common System. This formula is based on modern techniques of system engineering and takes into account the lack of complete system operational requirements. (See Fig. 1.) The ANDB has established two groups which are keystones of the process we are using for system development: the Systems Requirements Advisory Team and the Systems Engineering Advisory Team.

Operational requirements flow from many sources and are digested, consolidated, and clarified by the requirements team. The members are drawn from experienced operational personnel from the ANDB agencies. The Systems Engineering Advisory, composed of ANDB agency system engineers plus scientific consultants, postulate several systems which appear to meet the requirements. I say *appear* because we do not have complete and clear enough requirements to be certain that any system we analyze is adequate.

After some initial analysis, these systems will be subjected to a "Monte Carlo" simulation. The "Monte Carlo" technique is fairly idealized simulation, using graphical or mechanical techniques, wherein the forecast traffic is fed to the system. This technique has already been successfully used in air traffic control, initially by the Airborne Instruments Laboratory in 1947 and more recently by the Franklin Institute. In another field—automatic pilot development—analog computers have been successfully used in this type of analysis for several years.

The "Monte Carlo" system will be used to determine profitable avenues for further investigation and, as a feedback to the System Requirements Advisory Group, will furnish "ball park" figures on capacities, delay characteristics, and other critical features of the postulated systems under analysis.

It should be stated that in this stage of the process, a 1 to 1 time scale is not used. Therefore, the human responses are idealized to a great extent. That is why we go to the next step, 1 to 1 time-scale simulation.

One-to-one time simulation is considerably more expensive than the "Monte Carlo" technique, and as yet we do not have the capability of inserting the large numbers of aircraft that are predicted for the future. We will then examine the portion of the system for which the human responses are critical to establish the validity of the previous tests. As before, the output serves to determine the need for further, more realistic tests and as empirical data for the Systems Requirements Advisory Team.

The next step is actual system experimentation, whose expense increases by another order.

After this, and again to increase the realism of the analysis, in-service tests are carried out. At the successful completion of this phase, the ANDB can then publish system characteristics, and it can then recommend with considerable assurance the implementation of the proposed system.

The question may now be asked, "How do you get to the new system?" We have postulated the capacities required for the 1965–1975 period; the Monte Carlo and 1–1 simulator techniques permit us to start from the present system, subject it to increased traffic demands, examine analytically the critical portions of the system, and obtain data on simulated "fixes" or modifications. If the modifications do not work, we have neither delayed actual aircraft, involved expensive equipment, nor been forced to use it even though it is a blind alley. We then go through a series of modifications, checking at each stage with the Systems Requirements Advisory Group, on perhaps several promising avenues of evolution, until we find one or more solutions. (See Fig. 2.)

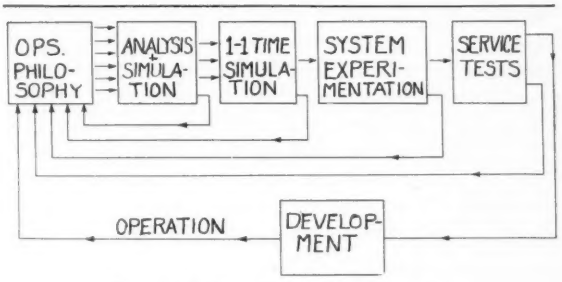

FIG. 1. System engineering flow chart.

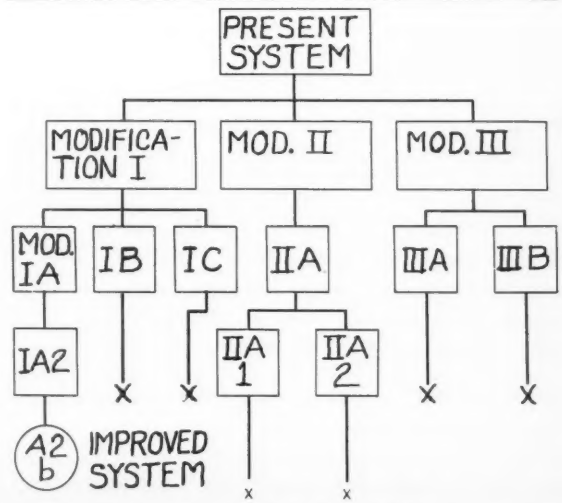

FIG. 2. Evolution by simulation.

In carrying out further tests, experimentation, or even in-service evaluation, we automatically carry with us the evolutionary steps that are necessary if the system is to be implemented.

In this manner, we expect to be able to answer the question, "But how do you get there from here?"

Now that I have exuded so much confidence, may I do some predicting on the character of the evolution which we will see in the next two decades.

Let me hasten to say that equipment may change, but our system will remain basically the same. Our system today is not homogeneous. There are several basic navigation systems all in use. There are at least two kinds of rules for separating aircraft, and of course there are as many ways of expediting aircraft as there are controlled areas in the system throughout the United States.

In this conglomerate system are the solid cornerstones for future progress. Our job is to emphasize and depend more on the cornerstones and gradually wean ourselves away from the crutches, "quick fixes," and expedients which tend to obscure the basic solidity of the system.

The first improvement we will see in the Common System will be through the gradually increased use of radar and the radar beacon to make radar an all-weather device. This will be associated with direct communications throughout the coverage volume of the radars. I believe that the CAA will accomplish this through remoting appropriate sectors to air defense radars, and we will see an occasional long-range radar operated jointly by the military and CAA in critical areas where air defense radar does not cover. The radar beacon will be used by military and civil aircraft. Those civil aircraft which will be expected to fly (even in a state of alert) will carry a beacon similar to the one under development. On the ground, there will be "defruiters" associated with the interrogater, and side lobe suppression may gradually be brought in by kit modification. The itinerant civil aircraft will have a "common man's" beacon, if American ingenuity can devise one. If not, in certain areas they will continue to be handled as in today's system, except when positively identified and tracked by radar.

As the improved air defense system goes into operation, I believe that CAA and air defense facilities will be combined, through mutual agreement, after comprehensive system tests now planned for in the Boston area. The ANDB has developed a plan for a joint civil-military traffic control experimental system environment in the Boston area. This plan includes analytical studies and experiments on integration of air defense and air traffic control. I expect that these tests will result eventually in fairly complete physical integration of air traffic control and air defense facilities. Great savings in personnel and communication facilities will be made through this cooperation. Military and civil personnel will work together in maintaining traffic control of all aircraft. Communication equipment during transition will be diverse for different classes of civil and military aircraft, using the same integrated ground distribution system. Voice channels will continue to be used as far as can be foreseen but will carry less and less load as automatic traffic control signaling and radar derived position data are implemented.

Traffic control in the en route zones—where density is low—will be based on a grain size consistent with density. Separation will always be based on interlocking closed-circuit techniques, utilizing a planned redundancy of communication for increased reliability.

In dense areas of operation such as terminal areas, the CAA will probably operate its own radars. A coarse system of separation will be in force as close as possible to the terminal area. In New York, for example, coarse control with possibility of holding may be used to approximately 20 miles, or even closer. Inside a certain volume, whatever it may be, there will be no holding. Aircraft proceeding into this volume will either make their scheduled landing or go around. Delay path computation, to regularize the landing interval, will first be accomplished manually and eventually automatically. The principle of the computer utilized for this delay path computation will be as follows:

(1) It will search for a nonconflicting path, with the least amount of delay.

(2) This path will be determinable in the air and identified with the aircraft's navigation system.

(3) It will be transmitted to the aircraft and modified as necessary.

(4) Aircraft will proceed only as long as positive instructions arrive. The aircraft receives alternative course of action for go-around at each stage of the approach.

(5) Delay will be inserted either positively or negatively through path change, programming speed change timing, and—only when necessary—differential speed change.

The role of the human controller through the next two decades will gradually reduce to a 24-hour stand-by operator for a lower capacity system in case of mechanical or electrical failures.

His first automatic aid will be an ingenious mechanism which will be a push-button traffic control clearance equipment. This equipment will permit him to transmit appropriate short clearances via selection on his display. Part of this system is an interlocking arrangement which will prevent issuance of conflicting or dangerous clearances. Equally ingenious and part of the communications system is a storage system that derandomizes his instructions and, through a scanning device, calls the appropriate aircraft and delivers the clearance. This clearance is voice or digital, whichever is appropriate. The voice may be canned and even speeded up in transmission. It should be remembered that position data, except probably altitude and associated identification, can be derived from the radar. Initially a clerk or clerks will associate the radar echoes with the appropriate identification, but this will grad-

ually be done by automatic computation. The computer can use the same rules for their association as the clerk can. Our problem is to find the minimum logical process that the clerk goes through and program it into the computer.

Finally, the comparison between clearance and position will be done automatically, and the controller will be by-passed. This will not be a difficult concept to accept if it is remembered that a machine will be used to prevent human error initially. The rest is a simple process that can be made more reliable than any human process. This may never require fewer controllers since the system will work 24 hours a day and will require three-shift operation.

It should be clear that this system, based on radar coverage wherever necessary, is a product of the international political situation. If, in the future, there is sufficient lessening of political tension to eliminate the necessity for a vast radar network, a simple digital air-ground link may be necessary whose output goes through the same communication network into the same digital computers that were used with the radar.

For navigation, today we are straitjacketed to a R-θ system, which, according to our latest studies, is reaching a point of diminishing returns in use of spectrum, cost, and complexity. Our first improvement will probably come through the elimination of four-course ranges. The VOR, DME, or TACAN will gradually give way to a non-line-of-sight system. A non-line-of-sight system presumably would have a better chance, both technically and economically, of actually being a common navigation system in the sense that it would be suitable for helicopters; high-flying, high-speed aircraft; and low-speed aircraft. The non-line-of-sight system may be a scanning system such as RADIO-WEB. This will probably never be replaced if our air defense radar system drops out of the picture. If radar stays in, the ultimate navigation system will be a radar-calibrated, short-term stability, self-contained system.

Landing and take-off navigation now done by GCA and ILS will gradually be eliminated because the navigation system will be accurate enough for low approaches. Automatic landing, technically on the verge of being a reality, may never be used in the common system except by military aircraft.

In conclusion, it must be admitted that it takes a certain amount of presumptuousness to predict such advance in the face of the slow progress we have seen in the last decade. I do not pretend that the only problem is that of devising clever methods with which to evolve into more modern techniques.

Actually, the corollary problems are more difficult. Our Government organizations need streamlining, and we do not have adequate test facilities for the Common System. But with a reorganized ANDB, a vitalized CAA, and the growing necessity for solution of these problems, I feel that the personnel engaged in research and development for the Common System will be permitted to solve the scientific problems and that the operating organizations will use our system as quickly as it can be devised.

Navy Requirements for Air Navigational Aids . . .

(*Continued from page 86*)

time intervals between aircraft at the "gate," and a number of situations may arise which will cause unsafe conditions to exist. For this reason, it is necessary to have an overriding human monitor whose job it is to provide manually the element of safety. Thus VOLSCAN can perform the function of flow scheduling but cannot assure the safety of the operation.

The SAGE system is a highly complex arrangement of information-gathering, computing, and disseminating equipment which, like VOLSCAN, was designed to do a special job. As now developed, SAGE does not solve our air traffic control problems. This same statement can be made about other computer systems which were designed to do specific jobs. They cannot be converted overnight to a purpose which varies substantially from that for which they were designed. A study is now under way to determine how the SAGE project and air traffic control may best be integrated in the interests of national defense.

The main value of these computers to the future air traffic control system lies in increasing our knowledge of highly complex computer system techniques and in having the ability to apply this knowledge to the solution of specific problems which are now arising in the air traffic control field and which will become more pressing with time.

A description of some recent ground tests and earlier flight tests of the ability of C-band air-borne weather radar to warn the pilot of hail shafts.

The Display of Hail Echoes on 5.5-Cm. Weather Mapping Radar*

Henry T. Harrison†
United Air Lines, Inc.

Introduction

United Air Lines published a report in 1954[1] which suggested that shafts of hail are identifiable on the C-band weather mapping radar scope by the appearance of sudden protuberances on the characteristic clamshell thunderstorm echo in the form of fingers, hooked fingers, or scallops. Prior to that time, other investigators had found no significant appearance on the PPI scope in connection with the fall of hail,[2,3] and theoretical studies were just as pessimistic over the possibility of distinguishing between rain and hail on standard weather mapping radars.[4] In 1955, the Committee on Radar Meteorology of the American Meteorological Society released a set of recommended procedures[5] covering the operation and interpretation of weather radars which included only one reference to hail echoes reading as follows:

"It has been suggested that hail storms are associated with sharp V-shaped notches or other incisions in very intense echoes when they are observed on reduced gain. These notches or holes in intense echoes are usually very sharp-edged, showing marked contrasts when the echo is observed on reduced gain. Attempts should be made to check the type of precipitation under such echoes as soon as possible."

Since this recommendation appears to be in conflict with the experience of the United radar group, it is the purpose of this report to review some of the findings of the 1953 radar flight-test project and to present additional evidence collected through ground observations of the C-band radar at Denver during 1954 and 1955. Our radar file now includes more than 8,000 radar scope photographs of which more than 400 were taken while hail was known to have been falling below or near the echo under observation and within 25 miles of the radar position. If we were to include those cases where hail was reported on the ground at the approximate time the radar picture was taken, the number would be roughly doubled.

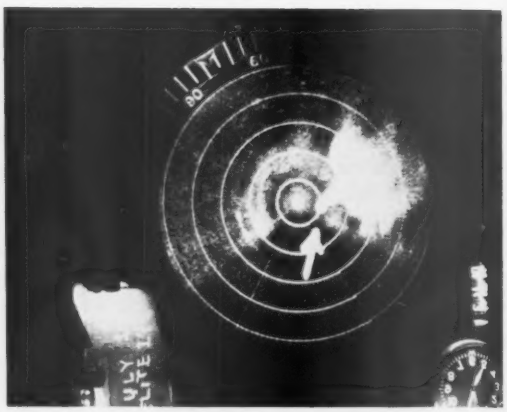

Fig. 1. Hooked finger.

The 1953 Flight Tests

Of 40 flights conducted with a DC-3 airplane in 1953 over the Western Plains and the east face of the Rocky Mountains, hail fell about the plane or within clear sight of the crew on 23 flights. Of 84 radar pictures selected from the best correlated instances of hail, a finger or hooked finger echo was found in 82 cases, scalloped edges in 32 cases, and a prominent U-shaped thunderstorm echo in 25 cases. The intensity of the parent thunderstorm echo was rated subjectively as strong in 58 per cent, moderate in 37 per cent, and weak in 5 per cent of all hail cases studied. In other words, nearly half of the hail-bearing thunderstorms were not considered sufficiently intense to be rated as strong echoes. The accompanying nine photographs have been selected from the 1953 flight-test file as examples of the types of radar echo which the United radar group learned to associate with hail shafts.

Location: 10 miles SE of Denver
Altitude: 9,300 ft. mean sea level

Presented at the Meteorology Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* The collection, correlation, and evaluation of all of the radar data from the United flight tests of 1953 was the joint product of a group composed of the following men: Capt. George W. Henderson; First Officer Donald J. Smith; Edgar A. Post, Project Coordinator; Frank J. Todd, Radar Technician; Melvin E. Balzer, Weather Observer; and the author.

† Weather Adviser.

Antenna Tilt: 5° up
Range Marks: 2-mile

Fig. 1: Another aircraft reported moderate hail when passing under this classical hooked finger 2 miles at 3 o'clock while the United crew watched the whole episode.

Location: 25 miles SSE of Denver
Altitude: 9,500 ft. msl

Fig. 2: An example of an enormous deposit of large hailstones on the ground. The thunderstorm which produced this shaft of hail is seen in the upper right with a shaft of hail still visibly falling from it along the horizon. Note the variations in the width of the shaft.

Location: 25 miles SSE of Denver
Altitude: 9,500 ft. msl

Fig. 3: The same hail deposit as viewed looking down on the Black Forest. Just west of this spot an official weather observer reported $2^1/_4$-in. hailstones covering the ground 4 in. deep.

Location: Near Monument, Colo.
Altitude: 14,000 ft. msl
Antenna Tilt: 5° up
Range Marks: 5-mile

Fig. 4: A contour picture of the second severe hailstorm which followed in the track of the first one (shown in previous two figures) and which left a ground deposit 25 miles long by 1 to 2 miles wide. Note the prominent U-shape with extended fingers.

Location: Strasburg, Colo.
Altitude: 9,000 ft. msl
Antenna Tilt: 3° up
Range Marks: 5-mile

Fig. 5: This picture shows an early stage in the formation of a hail finger 6 miles long starting 5 miles at 1 o'clock. The finger is too fuzzy and tenuous at this time to be rated as a hail echo, but the next picture will show the remarkable intensification in the following 7 min.

FIG. 2. Hail deposit on ground.

FIG. 3. Hail deposit on ground.

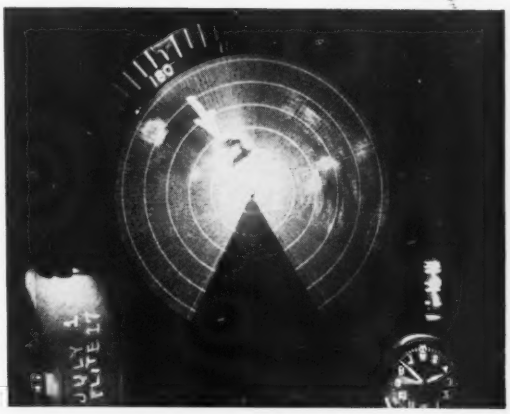

FIG. 4. U-shaped hail echo.

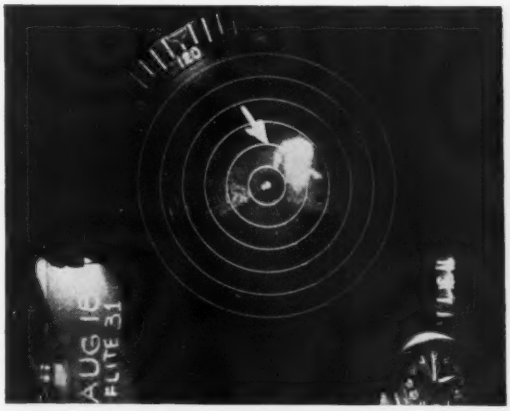

FIG. 5. Pointing finger.

FIG. 6 Pointing finger.

FIG. 7. Pointing finger.

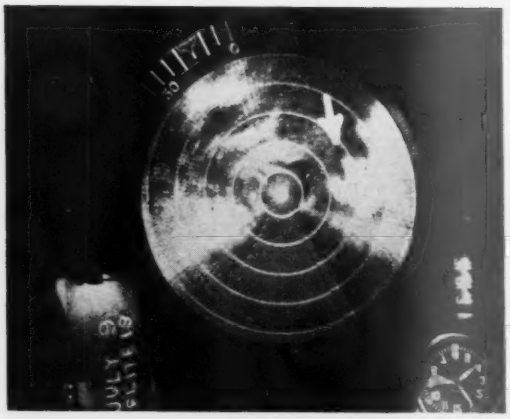

FIG. 8. Scalloped edge.

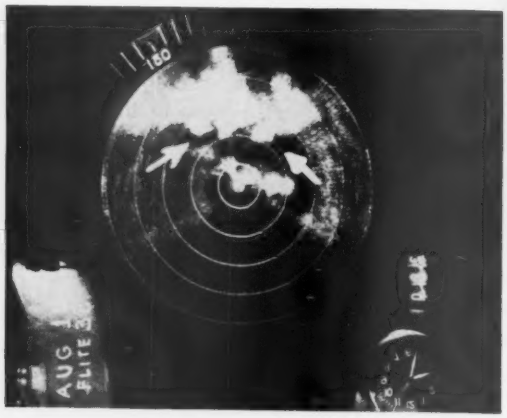

FIG. 9. Pointing fingers.

FIG. 10. Scalloped edge.

FIG. 11. Scalloped edge.

FIG. 12. Fingers.

Location: Same as in Fig. 5

Fig. 6: This picture was taken when the plane came abreast of the finger echo 7 min. later, using 2-mile range marks to give greater detail. Although hail was not definitely confirmed at this moment, the ground was completely covered with hail when the plane returned to this spot minutes later.

Location: Sidney, Neb.
Altitude: 8,500 ft. msl
Antenna Tilt: 3° up
Range Marks: 2-mile

Fig. 7: This picture on low gain setting shows a small, stubby finger projecting from a moderate thunderstorm dead ahead. A shaft of hail was plainly evident to the crew as the plane passed abeam of the finger 3 min. later.

Location: Byers, Colo.
Altitude: 8,600 ft. msl
Antenna Tilt: 5° up
Range Marks: 2-mile

Fig. 8: An example of scalloped edges forming a claw-hook starting 4 miles at 3 o'clock. A shaft of hail was visible out the cockpit window and a creek bed was covered with hail underneath.

Location: Flagler, Colo.
Altitude: 8,600 ft. msl
Antenna Tilt: 2° up
Range Marks: 2-mile

Fig. 9: A pair of pointing fingers 4 miles dead ahead with a single scallop 5 miles at 11 o'clock. The plane encountered moderate hail, heavy rain, and moderate turbulence when passing under the fingers 2 min. later.

THE 1954 AND 1955 GROUND TESTS

The preproduction model 5.5-cm. radar was used on the ground at Denver in 1954 while still installed in the DC-3 airplane. Pictures obtained during that year, like the flight tests of the year before, were limited by the wing shadow to an effective scope sweep of only 250° of the visible horizon. Pictures taken in 1955 included a full 360° sweep of all targets since the set was operated on a bench in headquarters with the antenna, transmitter-receiver, and power units installed in an aluminum house on the roof directly above. A masonite radome proved surprisingly effective in the operation of the 22-in. antenna which was employed in all of the pictures shown in this report. The series of eleven radar pictures which follow will show examples of the scope presentation when hail shafts were reported by unofficial observers in the 40-station hail-observing network sponsored by United Air Lines located within the Greater Denver area. In a number of cases, the hail shafts passed directly over the radar site, in others it was possible to correlate the scope picture with the occurrence of hail within narrow limits.

Range Marks: 5-mile
Antenna Tilt: 5°

Fig. 10: In this picture of a strong thunderstorm which is spreading southward up the South Platte Valley, plane is facing west. Note the pronounced scallop or blister showing 9 miles at 1 o'clock, also a smaller scallop 7 miles at 12 o'clock. Hailstones 3/4 in. in diameter were reported directly under the large scallop.

Range Marks: 2-mile
Antenna Tilt: 5°

Fig. 11: This is a magnified view of the same picture to show greater detail on the two scallops. When these scallops disappeared in 5 min., no further hail was reported in Denver, but a row of pointing fingers appeared in this same relative position half an hour later which were correlated with other reports of 3/4-in. hail 10 miles south.

Range Marks: 5-mile
Antenna Tilt: 3°

Fig. 12: Plane is facing west toward the Hogbacks and hills which show in the picture due to the relatively low antenna tilt. A moderate thunderstorm 10 miles at 9 o'clock shows a hooked finger on the west side and a pointing finger on the east side. Reports were received of 1/2-inch hailstones under this moderate storm.

FIG. 13. Pointing finger.

FIG. 14. Pointing finger.

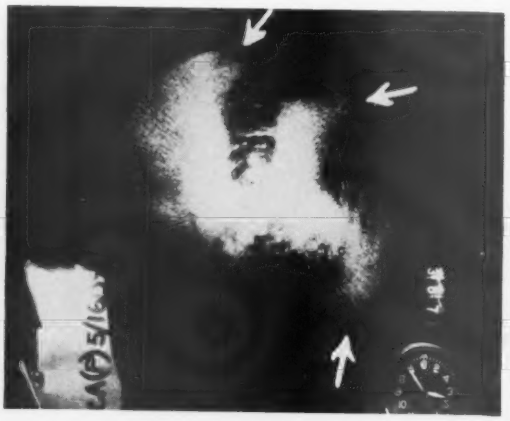

FIG. 17. Hooked fingers.

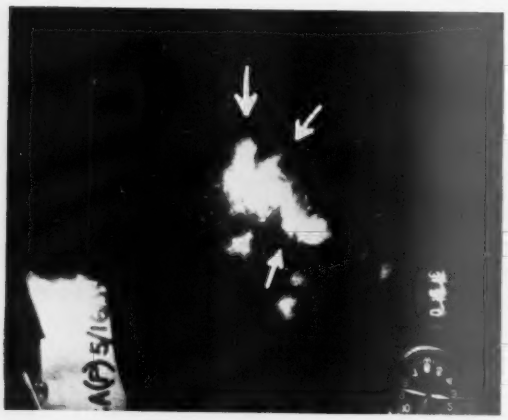

FIG 15 Hooked fingers.

FIG. 18. Pointing finger.

FIG. 16. Hooked fingers.

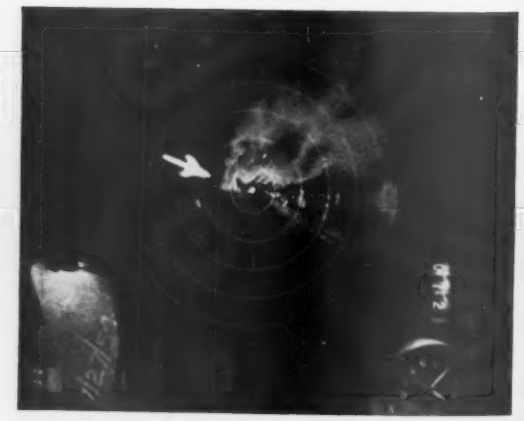

FIG. 19. Pointing finger.

Range Marks: 2-mile
Antenna Tilt: 5°

Fig. 13: Plane is facing west in an earlier view of the same thunderstorm shown in the previous picture. Small hail up to 3/8 inch was reported directly under this prominent pointing finger 4 miles at 9 o'clock.

Range Marks: 2-mile
Antenna Tilt: 5°
Contour: On

Fig. 14: This contour display, taken at the same time as the previous picture, shows only a moderate blackout in the core of the storm but a well-defined vein running straight down the pointing finger.

Range Marks: 5-mile
Antenna Tilt: 7°

Fig. 15: This pinwheel echo is composed of three hooked fingers as a brisk fall of small hailstones passed directly over the radar site. This moderate thunderstorm left a wide swath of hail across the city to produce considerable leaf stripping in many areas as the storm moved NNE from Littleton, 10 miles to the SSW.

Range Marks: 5-mile
Antenna Tilt: 7°
Contour: On

Fig. 16: This contour display of the storm shown in the previous picture clearly delineates the core of the storm plus its three projecting fingers. Total precipitation at the radar site was 0.12 in.

Range Marks: 2-mile
Antenna Tilt: 9°

Fig. 17: This magnified view of the previous two pictures, taken 8 min. prior to them, shows the structure of the fingers as they first moved in on the radar. 3/8-in. hail is falling at this moment 3 miles to the west (left) and started at the radar site 5 min. later.

Range Marks: 2-mile
Antenna Tilt: 5°

Fig. 18: In this contour picture, the plane is facing north toward a heavy thunderstorm moving in from the NW. A heavy fall of 3/4-inch hail hit the plane 10 min. later as the prominent finger 2 miles at 10 o'clock moved over the field. Light hail actually started 7 min. after this picture was taken.

Range Marks: 2-mile
Antenna Tilt: 5°

Fig. 19: This contour picture was taken 5 min. later just before the first hail arrived at the airport. The heavy fall is still 5 min. away. Total rainfall in the storm was 0.42 in. and windgusts hit 60 m.p.h. from the NNW.

Range Marks: 5-mile
Antenna Tilt: 4°

Fig. 20: In this picture of the same retreating storm, part of the echo is lost in the right wing shadow, but a row of fingers is plainly evident on the backside. Just SE of the airport, an extremely heavy fall of hailstones as much as 3 in. long caused damage to homes and buildings estimated at one million dollars.

After reviewing the radar hail pictures obtained on the ground at Denver during 1954 and 1955, a selection was made of 32 pictures which appeared to offer representative samplings of conditions in which the occurrence of hail within a radius of approximately 25 miles could be positively correlated with photographs of the 5.5-cm. radar scope taken at Stapleton Airfield. Following is a recapitulation of a subjective survey made of these pictures along the same lines employed during the evaluation of the 1953 flight tests which were summarized earlier in this report:

	No.	Per Cent
Cases examined	32	100
Cases where fingers, hooked fingers, or scallops were prominently displayed	31	97
Cases where fingers or hooked fingers were prominently displayed	27	84
Cases where scallops provided only identification of hail	4	13
Cases with prominent U-shape to the parent thunderstorm echo	4	13

It will be noted that the ground results differ in degree from those of the 1953 flight tests but that the pattern of identifying hail echoes from the appearance of *fingers*, *hooked fingers*, or *scalloped edges* on the scope seems to be unmistakable. One major difference in the two sets of figures is that the U-shaped thunderstorm echo did not figure as prominently in the ground tests as it did during the flight series as suggesting hail. Other correlations have indicated that the U-shaped echo is very often associated with heavy thunderstorms, but it would appear now that this form is not particularly indicative of hail by itself.

With respect to the intensity of the parent thunderstorm echo, a subjective rating was given to each of the 32 pictures at the time the hail was falling. Again, the results were similar to those obtained in the 1953 flight tests.

FIG. 20. Fingers.

	No.	Per Cent
Cases examined	32	100
Strong echoes	17	53
Moderate echoes	14	44
Weak echoes	1	3

The Sampling

There is naturally some difficulty in reconciling the positive results of the United radar tests with the failure of experienced investigators in other parts of the country to find similar correlations while using X-band and S-band radars. Since the wave length presumably would not be a major factor in altering the general configuration of weather echoes (except for attenuation on the back side of strong echoes in the case of X-band), some thought was given to the possibility that the finger echoes found so frequently in the United tests might not necessarily denote hail shafts when encountered in other parts of the world. Insofar as hail was concerned, all tests with the 5.5-cm. radar were conducted in the states of Colorado, Wyoming, Nebraska, and Kansas. This area actually embraces the belt of highest exposure to damaging hail found anywhere in the county—a belt wherein hail crop insurance rates run as high as 20 per cent and where the frequency of hail damage to aircraft in flight runs considerably higher than in any other section.[6,7] It would appear, therefore, that any method which will aid the pilot in avoiding damaging hail over the Western Plains of the United States should prove to be invaluable to air navigation in that area even though the procedure might conceivably have to be modified when applied elsewhere.

Possible Explanation of Hail Fingers

The National Thunderstorm Project,[2] conducted in Florida and Ohio, concluded that hail is found during the mature stage of thunderstorms but not in every thunderstorm. Over the Western Plains, on the other hand, there is some reason to feel that hail occurs somewhere at some stage in nearly every storm which develops over that section.[6] Furthermore, it has been observed that shafts of large hail over the Western Plains and the east slope of the Rockies characteristically fall from the sides or the overhanging canopies of cumulonimbus clouds, often considerably removed from the heavy rain core inside the storm. Observations and pictures also show that big hail shafts appear quite suddenly along the sides of the thunderstorm cloud and that they change perceptibly in breadth and intensity in a matter of seconds. If these observations are valid for the typical hail storm, then we have a reasonable explanation for the sudden appearance of protuberances along the periphery of thunderstorm echoes in the form of fingers, hooked fingers, or scallops.

Since it is fairly apparent that the radar beam will not discriminate between rain drops and hail stones, we can be certain that hail which falls inside the heavy rain core of the storm will not be displayed uniquely on the radar scope. It is true that the United sampling included numerous cases where ice balls were encountered well inside the thunderstorm, but nearly all of these were logged by the Weather Observer as sleet, graupel, or small hail—probably not more than 1/4 to 3/8 in. in diameter. Fortunately, this would present no problem to the pilot since we know that the threshold diameter of damaging hail to aircraft structures is between 3/4 and 1 in.[8]

Limitations to Finger Identification Method

A number of limitations were mentioned in the initial United report[1] on C-band radar which should be kept in mind when employing the empirical rules of identifying large hail shafts by the appearance of protuberances on thunderstorm echoes. These might now be reappraised as follows:

(1) Constant monitoring of the cockpit scope will be essential to detect the hail developments when flying in or near thunderstorm conditions.

(2) The radar scope will not be capable of giving warning of hail falling inside the rain curtain of the thunderstorm.

(3) A fresh fall of hail cascading suddenly on the plane from an overhanging canopy will not be reflected by the radar beam in time to give warning to the pilot.

(4) All finger and scallop echoes will not necessarily denote hail ahead of the plane, but a good rule for the pilot to follow is to allow an extra margin between the plane and the storm echo whenever protuberances appear. Weak protuberances showing up on the storm edge, or even detached slightly from the storm edge, may represent the first stage in the development of a prominent hail finger.

(5) The finger identification may not be as valid in other parts of the country as it is over the Western Plains and the east slope of the Rocky Mountains where all of the United data was collected.

Conclusions

The results of the 1954 and 1955 ground tests confirmed the 1953 United Air Lines flight project conclusion that C-band air-borne weather radar is capable of warning the pilot of hail shafts ahead of his plane in approximately four cases out of five. Identification of hail shafts on the radar scope is inferred empirically by the appearance of protuberances from the edges of the parent thunderstorm echo which change form and intensity appreciably in a matter of half a minute or less and which characteristically take the following forms: (1) the pointing finger, (2) the hooked finger, and (3) the scalloped edge.

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[2] Byers, H. R., and Braham, R. R., Jr., *The Thunderstorm*,

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[3] Ayer, R. W., and White, F. C., *The Development of An Airborne Radar Method of Avoiding Severe Turbulence and Heavy Precipitation in the Precipitation Areas of Thunderstorms and Line Squalls*, American Air Lines Flight Engineering Navy BuAer Contract No. a(s) 9006 Final Report on Task No. 1, 1949.

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[6] Beckwith, W. B., and Harrison, H. T., *A Reexamination of Hail Patterns Over Western United States*, United Air Lines Meteorology Circular No. 35, p. 5, 1950.

[7] Souter, Robert K., and Emerson, Joseph B., *Summary of Available Hail Literature and the Effect of Hail on Aircraft In Flight*, NACA TN 2734, pp. 58, 87, 1952.

[8] Anon, *Report of Impact Test on Metal Wing Sections and Propeller Dome with Artificial Hailstones*, Memorandum Rep., Aircraft Development Div., Structures Section, CAA Technical Development Experimental Station, 1949.

Cooling Electronic Equipment in High-Performance Aircraft

(*Continued from page 81*)

requirements by 75 per cent. Actual airflows to be expected with a simple ram system are also shown. It indicates that, at sea level, the weight flow may be 275 per cent of that needed. This oversupply of cooling air may be had only at the expense of additional drag. The airplane manufacturer must accept the responsibility for reductions in this field.

Fig. 17 defines the drag loss associated with providing ram airflow in current aircraft. A substantial variation is apparent as a result of changes in both altitude and speed. The curve for cruise has been used as the basis for calculating the fuel expenditures previously quoted. An air cycle system as proposed will weigh about 15 lbs. per kw. Fuel cost at cruise is 12 lbs. per hour. For a 2-hour mission, the total weight becomes 39 lbs. This is equivalent to 26 watts cooling capacity per pound. Compared to the refrigeration cycle under similar conditions, where the capacity is 32 watts per pound, there seems to be no reason for reverting to ram air. Emphasis is immediately focused, then, on increased utilization of the air supply. A reduction by the 75 per cent previously indicated as practicable would raise the cooling capacity per pound to 104 watts.

No magic that the airplane manufacturer can produce in heat absorption capacity will replace the need for electronic equipment to be designed as heat-transfer apparatus. This requires that the designer of electronic modules provide:

(1) Minimum power requirement.

(2) Suitable control of airflow.

(3) Maximum effective temperature.

(4) Highest possible air temperature differential across the unit.

Cooling electronic equipment in an aircraft is a problem. It is a problem for the airplane manufacturer and for the electronic equipment manufacturer. More effective treatment of cooling problems can produce a lighter, simpler, and more reliable aircraft. Sound engineering principles can be applied to the solution of these problems. Adequate appreciation for heat-transfer phenomena is necessary. Only then can airplane and electronic designers define a set of standards to which both may work effectively. It is proposed that this be done in the course of developing equipment to suit the requirements of the electronic package described.

Ram air cooling of electronic equipment can be made suitable for aircraft which do not fly at high supersonic speeds. It can be done only if, during the design of such equipment, adequate consideration is given to electrical, mechanical, and heat-transfer problems. Weight is the common denominator which may be used to obtain the best balance in equipment design. Definitions of weight flow, air temperature, and pressure drop are needed. Active work on the part of both electronic and airplane designers is required to set up standards that will provide the best aircraft performance. But most important, the easiest watt to dissipate is the one that is designed out of the equipment.

By providing the proper thermal environment, the aeronautical engineer can assist the electronic engineer in improving the performance and dependability of avionic equipment.

Cooling Procedures Necessary to Avionic Reliability

James P. Welsh*
Cornell Aeronautical Laboratory, Inc.

AVIONIC EQUIPMENT has become of significant importance to the aircraft industry. Modern aircraft rely more and more on avionics, and, consequently, the performance of aircraft is becoming closely related to that of the electronic equipment. The aviation industry has, to a certain extent, looked at electronics as a necessary evil, and it has for some time been apparent that the mysterious "black boxes" are here to stay. In fact, the quantities of vacuum tubes in use per aircraft are increasing so rapidly that one wonders if the point of diminishing returns will be reached in the immediate future.

Aeronautical designers may feel that all avionic equipment problems can best be solved by electronic experts, and aeronautical designs may not seriously influence electronic performance. In some respects, this is true. However, there is at least one aspect of avionics in which aeronautical engineers can indirectly influence the performance of the equipment—namely, heat removal. Certain problems associated with the cooling of avionic equipment are herein outlined in an attempt to show how aeronautical designers can aid in improving avionic performance. An increased appreciation of the cooling requirements of avionic equipment can ultimately result in better cooling and in better electronic functioning, especially in terms of reliability.

Electronic reliability has been mentioned in electronic circles as being analogous to sin—that is, it is something we preach about but are frequently tempted to overlook. We all know that air-borne electronic equipment must be extremely reliable. However, this word "reliability" is somewhat nebulous and requires a definition peculiar to the specific performance required. Numbers which have been assigned to define this highly desirable characteristic usually are related to a statistical prediction of the functioning life of the equipment based upon the anticipated life of the component parts. The life of the parts is directly influenced by many factors which are interrelated and sometimes difficult to isolate. As in a chain, most electronic circuits in equipment are linked together. Should any single part or connection fail to operate properly, the entire equipment may fail. Temperature effects are among the important factors which determine the life of electronic parts.

Avionic equipment has an extremely low electrical efficiency. Only a small percentage of the electrical power consumed is converted into useful output. As a result, most of the input power is transformed into undesirable waste heat. The removal of this heat from within the equipment, its transfer, and its ultimate disposal are seldom simple or easily solved problems. Excessive temperatures in avionic equipment can readily be obtained unless care is exercised in the design of the cooling system. Such temperatures may lead to malfunctioning and failures of avionic equipment and indirectly impair aircraft performance.

The effects of temperature upon electronic parts are complex. Not only is there the possibility of immediate total failure but also the temperature-caused variations of electrical characteristics can cause a change in electronic performance which, in turn, can result in malfunctioning. It has been difficult to ascertain the effects of temperature upon avionic reliability because the failure of electronic parts is not simple. Many parts do not fail immediately when they are overheated but, instead, deteriorate slowly. This reduces the potential life of the parts, and they may later fail without warning at an inconvenient time. This situation is further complicated by the optimistic thermal ratings of parts and equipment. Unfortunately, these ratings are usually expressed in terms of ambient temperature—i.e., the temperature of the medium surrounding an isolated part. However, an ambient rating alone is not satisfactory as it does not include the radiation and conduction interactions with nearby hot spots. These effects can be significant when closely spaced parts have a high heat concentration, and, consequently, overheating may occur even though the ambient rating is not exceeded. Fig. 1 defines these terms.

The mechanism of heat transfer within avionic heat sources is of interest. (See Fig. 2.) In brief, vacuum

Presented at the Electronics Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Head, Electronics Section, Industrial Division.

ubes transfer their heat primarily by radiation so hat most of the heat arrives at the plate. The plate n turn radiates heat through the vacuum to the glass nvelope. Most of this radiation is absorbed by the lass. The envelope must be cooled by a method which ill provide a uniform temperature distribution and ill not impair the radiation characteristics of the glass. ube shields are necessary for electrical reasons but are requently heat traps. (See Fig. 3.) Ideally, the hield should remove the heat from the bulb and trans- er it into the chassis, as shown, or it should transfer he heat into some other media such as air. Fig. 4 hows a liquid-cooled tube. Note the radiation halo C" and the strongly heated convection currents. ubes operate at fairly high temperatures, and some re rated for hot spot temperatures as high as 250°C. owever, there are definite limiting temperatures hich cannot be exceeded. As a rule, vacuum tubes eteriorate rapidly when the bulb temperatures are ignificantly increased over 175°C.

Resistors are another heat source which must be onsidered. In general, the heat is transferred into he surrounding air by convection, into surrounding ob- ects by radiation, and to the points of attachment by onduction through the leads. Transformers and in- uctors also reject considerable quantities of heat. Unfortunately, the windings of these devices, wherein he heat is produced, are electrically and thermally nsulated so that the resistance to heat transfer from he source to the surface is relatively high. The heat from iron core devices is rejected by radiation and con- vection to the surroundings, together with conduction to the chassis. Liquid-immersed transformers are now being utilized in some applications. This technique

Definition of Avionic Cooling Terminology

Heat Dissipation
The difference between the electrical input and output of an electronic device, usually expressed in watts.

Unit Heat Dissipation
The heat dissipation per unit surface area, usually expressed in watts per sq.in.

Heat Concentration
The heat dissipation per unit volume, usually expressed in watts per cu.in.

Thermal Resistance
The resistance to heat transfer, in °C. per watt.

Ultimate Sink
A body of matter to which thermal energy, in its path from a heat source, is ultimately delivered, and of sufficient mass to cause its temperature to remain constant—e.g., infinite heat storage capacity.

Thermal Environment
The condition of (1) fluid type, temperature, pressure, and velocity; (2) surface temperatures, configurations, and emissivities; and (3) all conductive thermal paths surrounding an electronic device.

Ambient Temperature
The fluid temperature surrounding an electronic device—one of the factors contributing to the thermal environment.

FIG. 1.

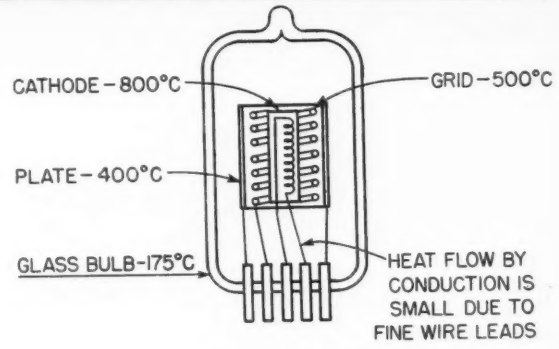

FIG. 2. Heat transfer in a vacuum tube.

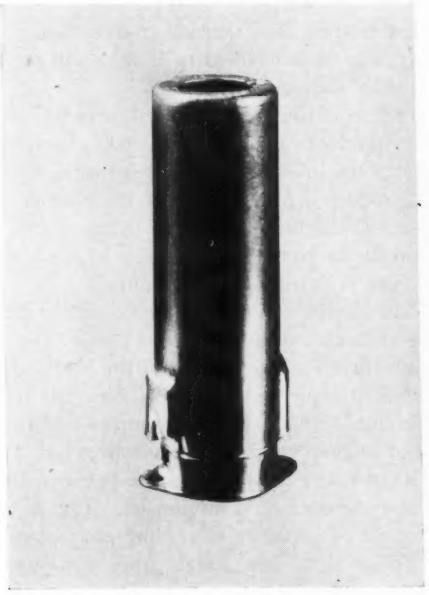

FIG. 3 Tube shield.

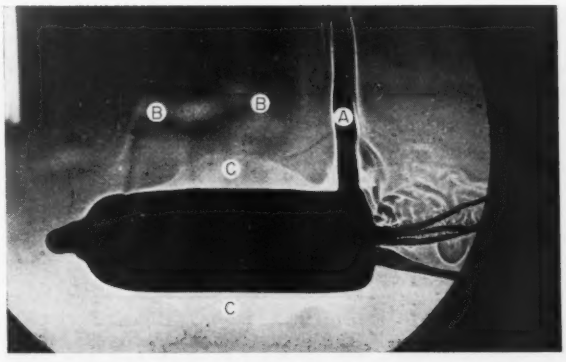

FIG. 4. Observation of the heat distribution of a subminiature tube.

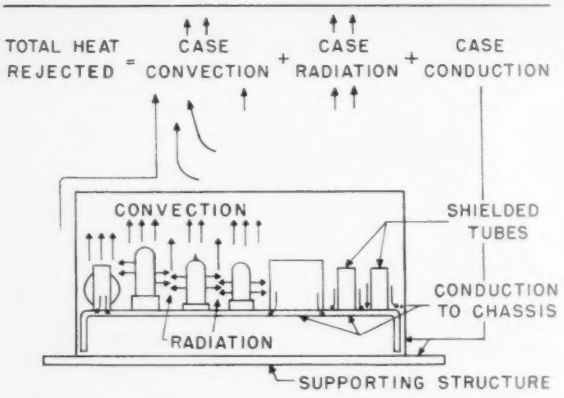

FIG. 5. Natural heat flow paths in an avionic equipment case.

can, in some instances, result in a lighter unit in spite of the added weight of the coolant and the case. The physical size and weight of most electronic heat sources is predicated upon their thermal characteristics. Consequently, any improvement in cooling will permit the use of smaller components.

Fig. 5 presents the natural heat flow paths within an avionic equipment case. The heat flows from the heat sources into the internal air or other media, into other nonheat-producing parts, and into the chassis. If the case is sealed, the heat ultimately is transferred to the inner, and thence to the outer, surface of the case. The heat is then rejected to the surrounding air. Ventilated cabinets will permit convective airflow and also heat the surrounding air. Forced cooling, of course, will permit direction and control of the heat.

Electronic designers attempt to reduce the temperature difference between the heat sources and the outer surfaces of avionic equipment enclosures, or, if forced cooling is used, the temperature rise between the heat sources and the coolant is minimized. Fig. 6 presents a comparison of methods of cooling electronic equipment. These data are rough approximations and demonstrate the relative magnitudes of various heat-removal techniques. In general, decisions of cooling method selection and internal equipment design are within the bailiwick of the electronics designer. The thermal design of avionic equipment is frequently

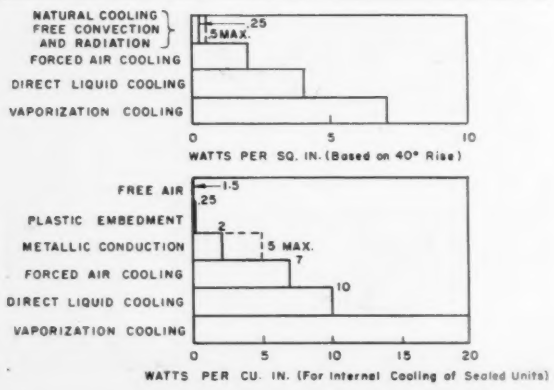

FIG. 6. Comparison of methods of cooling.

difficult. Circuit functioning, especially at high frequencies, necessitates short leads and the mounting of temperature sensitive parts in close proximity to heat sources. The requirements for lightweight, small equipment mandate dense packaging and the minimization of metallic heat conductors. Some miniaturized equipments are so densely packaged that free air convection between parts is impaired, and the pressure drop with forced convection can be excessive. This situation is further complicated by the constantly increasing requirements for improved operation at even higher temperatures.

Because of the multiplicity of heat flow paths and the complex part configurations, electronic thermal design is not very precise. Thermal phases of engineering associated with electronics have unfortunately lagged behind circuit development and functioning. As a result, cooling design is not as thoroughly developed as it should be. In some respects, it is more of an art than a science.

In general, it is possible to predict roughly the thermal performance of electronic equipment based upon empirical data and the basic heat-transfer laws. Certain cooling techniques with slight modification and some experimentation can be directly applied to specific designs. But it must be recognized that the thermal design of electronic equipment has not been reduced to an exact mathematical analysis. Fortunately, the total heat rejected from electronic equipment is usually known with fair accuracy, and thus the order of magnitude of any specific cooling design can be determined. Work in this field is now under way, and it is anticipated that some of the thermal design problems associated with electronics will be eased.

In avionic equipment, the ultimate sink is not normally within the direct control of the electronic designer. Usually, the ultimate sink is that portion of the earth's atmosphere through which the aircraft is flying. Consequently, all of the heat is rejected into the aircraft for direct or indirect transfer to the atmosphere. Thus, the aircraft designer should provide a good heat path between the avionic equipment and the ultimate sink. Fig. 7 shows a simplified circuit analogy of the heat paths from avionic equipment to

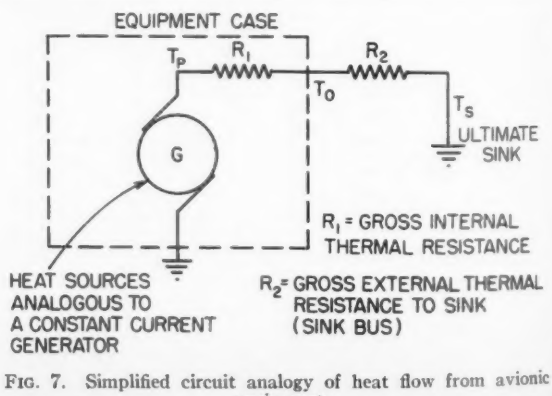

FIG. 7. Simplified circuit analogy of heat flow from avionic equipment.

the ultimate sink. Note that all temperatures are functions of the temperature of the sink and the thermal resistance R_2, both being beyond the control of the electronic designer. The temperature T_0 at the junction of the cooling path from the sink and the path from the heat sources is of particular importance. At this point, the cooling paths provided by the avionic and air-frame designers join and must be compatible. Some difficulty and misunderstanding have occurred in this matter, and the result has been overheating and impairment of avionic reliability.

Both electronic and aeronautical designers have been guilty of mismating cooling systems. Frequently, the avionic equipment and the air frame are produced by separate organizations which specialize in their respective fields. Unfortunately, communications and liaison have not always been ideal, especially in the matter of cooling which is frequently of secondary interest to both groups. Consequently, it is recommended that the cooling requirements for each avionic equipment be more accurately defined and that aircraft manufacturers give more consideration to meeting such specific requirements. In particular, ambient temperature alone should not be utilized as the sole definition of the thermal situation. Further, not only should the thermal environment prior to the installation of the equipment be known but also, and most important, that which results when the equipment is installed and operating. The heat rejected from avionic equipment can significantly modify the initial thermal environment.

An overall-systems approach to avionic equipment and aircraft cooling is generally necessary. It is important that the heat be directed and controlled in specific paths to the ultimate sink. Total integration of the heat rejected by all similar heat sources in aircraft into the desired paths should lead to improved functioning, in terms of not only enhanced reliability but also lower cost, reduced maintenance, less weight, and probably increased aircraft flight performance.

Transistorized avionic equipment will also require cooling but of a more specialized type. Transistors are even more critical in their cooling demands than vacuum tubes. It is true that transistors can operate at milliwatt power levels compared to a minimum level of at least one watt for the average vacuum tube. Further, the overall efficiency of transistors is almost double that of many vacuum tubes. However, transistors are extremely temperature sensitive. Transistor action is an electrothermal phenomenon, and the electrical characteristics of transistors will vary with temperature. Germanium transistors perform well up to approximately 50°C. and marginally to 100°C. surface temperature. Silicon transistors are usable to 150°C. and perhaps higher. In general, most transistor circuits in use today require temperature stabilizing circuits in order to permit operation over a temperature range as small as 50°C.

It appears that it may be desirable in some applications to provide transistorized avionic equipment with a constant temperature environment in order to achieve optimum performance and reliability. Recommending the use of a heating and refrigeration system for avionic equipment may at first sound impractical. However, the total power consumed and the heat to be transferred can be extremely small compared to that of a comparable equipment utilizing vacuum tubes. Thus, the total size and weight of the transistorized device, including its refrigeration system, can be less than that of its vacuum-tube equivalent.

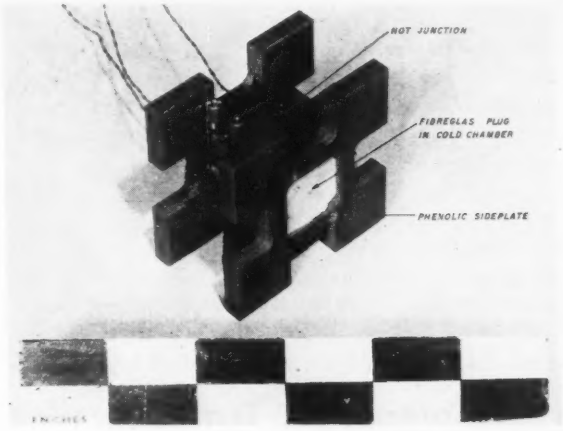

FIG. 8. Experimental cooling pile.

Future avionic cooling systems may employ not only refrigeration and expendable vaporization cooling but also certain special techniques such as thermoelectric cooling. Thermocouples commonly provide a means of conversion of heat to electrical energy. This conversion is also reversible, and thus thermoelectric junctions can be connected in series to form a pile which, when energized, will act as a simple heat pump. Direct cooling is provided electronically without moving parts or fluids. Fig. 8 presents a Peltier cooling thermopile. This crude model was fabricated to investigate the feasibility of this technique. It displayed an apparent efficiency of 17 per cent at 1.2 watts and produced a temperature drop of 16°C. Transistors, for example, could be cooled with this device. It is not suitable for immediate application, but it is anticipated that thermoelectric cooling will ultimately become a technique used for at least some special situations.

The reliability of avionic equipment can be significantly enhanced if the equipment is properly cooled. It is recommended that aeronautical engineers place increased emphasis upon supplying the thermal needs of avionic devices. Air-frame manufacturers should attempt to provide adequate spaces for electronic equipment. Piecemeal scattering of avionic devices into the remaining voids of an air frame should be avoided wherever possible. Conservatism must be the aim of every design for reliability. If an aircraft is to be truly dependable, an adequate margin of safety must also be included in the avionic design. Aircraft reliability can be achieved only if the aeronautical, electronic, thermal, and mechanical designs are well executed in a conservative fashion.

Helicopter Flight Trainer*

Circumstances which led to the development of a helicopter synthetic flight trainer and the work necessary to arrive at a practical concept of a device.

Luis de Florez† and E. K. Smith‡
The de Florez Company, Inc.

FIG. 5.

ONE OF THE most important factors in training for modern combat has been the development of synthetic training devices and methods. With the aid of such devices, real action can be recreated or simulated virtually under actual conditions.

During World War II, several hundred different synthetic training devices were put in operation by the Navy, including gunnery trainers, bombing trainers, flight engineer panels, navigation devices to teach dead reckoning and celestial navigation, radio and radar simulators—together with many other partial trainers and visual aids to supplement the major training devices. In fact, the principles of synthetic training were found to apply to training for all complex equipment.

Perhaps the most spectacular of such training devices which emerged from the program was the "Operational Flight Trainer," which simulated the flight of large and complex aircraft with such accuracy that it was possible to reproduce instrument flight with extraordinary realism.

As aircraft became larger and more complex, it became evident that the Link trainers then available, which had been so successful in teaching the principles of instrument flight and radio navigation, were inadequate for advanced flight training from the point of view of both flight characteristics and operation. An extensive study revealed that the components required for the accurate simulation of flight were available but that the difficulty in combining them in a workable device lay in inadequate analysis of flight itself and in the selection of characteristics on which to base an analog device to simulate the operation of a given type aircraft.

After further study in conjunction with the NACA and the Bell Telephone Laboratories, an acceptable simplification of the flight equations was brought about to form the basis for an analog computer to recreate adequately the flight of the PBM flying boat. This work resulted in the building of the first electronic flight trainer which was put into operation in 1943 and served as a model for a whole series of flight trainers for other combat and patrol aircraft.

The PBM trainer consisted of the fore part of the hull of the aircraft, including all instrument controls and panels, along with a duplicate instructor's control and observation panel. It was unlike the Link trainer in that it did not move and therefore did not exert the acceleration forces which were previously considered to be essential for flight simulation on instruments. It was, however, provided with appropriate vibration and noise which affected the crew in such a manner that, after a short period of following the instruments, the stationary cockpit appeared to move in a natural fashion.

Presented at the Flight Safety and Training Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* The authors desire to acknowledge the keen interest and cooperation on the part of the Navy and the many individuals connected with the development, in particular the Special Devices Center of the Office of Naval Research, the Bell Aircraft Corporation, and our associates in The de Florez Company.

† Consulting Engineer.

‡ Chief Engineer.

After establishment of the utility of the flight trainer or simulator and its general acceptance by the services, it was logical to resort to the knowledge gained in simulators to produce a flight trainer for the helicopter. The problem in this case, however, was quite different, not only because helicopter flight differs from that of fixed-wing aircraft but because the simulation of visual flight instead of instrument flight calls for a totally different technique.

Despite these differences, the basic factors governing the design of a helicopter trainer were nevertheless the same. As in the flight trainer, it was necessary (a) to determine the helicopter characteristics by theoretical study and from this to establish a basic analogy, and (b) to make a skillful compromise between absolute accuracy and practical considerations in order to reduce complexity as far as possible and yet serve the main purpose—instruction.

Flight trainers of any type are all training devices, not flying machines. They must be sufficiently realistic and operationally correct in functions to train effectively, and yet they must be capable of being produced with due regard to first cost, operation, and maintenance. The flight trainers—whether a fixed-wing or helicopter—have, of necessity, limitations and shortcomings, but, by the same token, they have advantages over actual aircraft for certain phases of training. They afford the opportunity to observe and coach students under instruction together with the means of creating emergency conditions without hazard to test the students' proficiency and reactions. These features, combined with the low operating cost and the almost continuous availability of the trainer regardless of flight conditions, constitute an important argument for any synthetic device to which the helicopter flight trainer is no exception.

During World War II, a helicopter flight trainer, probably the first of its kind, was built by the Navy's Special Devices Division of the Bureau of Aeronautics and erected in the Coast Guard hangar at Floyd Bennett Field (Fig. 1). This device, designed to represent the Sikorsky (HNS) helicopter, consisted essentially of a cockpit replica hung from an overhead traveling crane which permitted it to move in any direction horizontally in combination with a mechanism to raise and lower it and to rotate it—all in response to the controls. The device was primarily mechanical, the flight characteristics being reproduced by cams and gears for computers utilizing actual motion for simulation of flight. Although it was relatively crude owing to the lack of theoretical knowledge available at the time and limited in its travel, this trainer was useful in teaching, in the first few hours of instruction, coordination of the controls and hovering. It was also found useful for practice in maintaining manual operating skill which may be lost after long lapses between helicopter flights.

The device, although essentially experimental, was used in the early stages of training of helicopter students for the Coast Guard and Navy. It was, however, large and unwieldy, occupying valuable hangar space, and requiring heavy structural supports. Consequently, when the helicopter flight training activity was moved to Lakehurst and later to Pensacola, it was dismantled, stored, and in due course forgotten.

In 1950, the growing need for Navy helicopter pilots and the scarcity of helicopters renewed the Navy's interest in some form of synthetic trainer for primary instruction. A preliminary study was made to determine the need and practicability of possible training devices. This study established a need for a synthetic trainer and at the same time brought out the necessity of further study to determine whether a practical device could be evolved owing to the difficulty of reproducing visual flight conditions which, of necessity, governed helicopter flight.

In order to obtain firsthand information on the nature of the problems involved in helicopter training, one of the authors (de Florez) was directed to take the helicopter course at the Navy School in Lakehurst which he completed in 1951. His experience there confirmed the need for a helicopter trainer and uncovered several areas in which synthetic training and practice could be substituted for actual flight time if equipment were available. This would permit more advanced air training in the allotted time for the course and, consequently, the production of more proficient pilots in the same period of time.

About that time, the Bell Aircraft Corporation became interested in the possibility of a synthetic device to improve and facilitate the training of helicopter pilots. As a result of this community of interests, the Bell Aircraft Corporation underwrote a basic study of the helicopter training problem by the de Florez Company, which led to the design and production of a prototype trainer, under the sponsorship of the Special Devices Center, Office of Naval Research, to be tested at the Navy's helicopter school at Pensacola.

Before initiating design studies for any specific synthetic training equipment, it is necessary to make a preliminary survey. Because the steps involved in this case are essential to the application of synthetic training techniques to any training problem, they are outlined as follows:

(1) The analysis of the training program in order to define, in broad functional terms, the major problems arising in helicopter training. This step included the determination of skills which required the greatest number of hours in training and of any particular skills in which proficiency was especially difficult to attain.

(2) The definition of the objectives of the prospective training device or establishment of requirements. This step included the consideration of both the training tasks for which the device was to be utilized and the limits, or levels of advancement, for which it was believed to be economically and functionally practical. It also included a forecast of its probable utilization methods and a consideration of the extent to which special features inherent to synthetic trainers should be

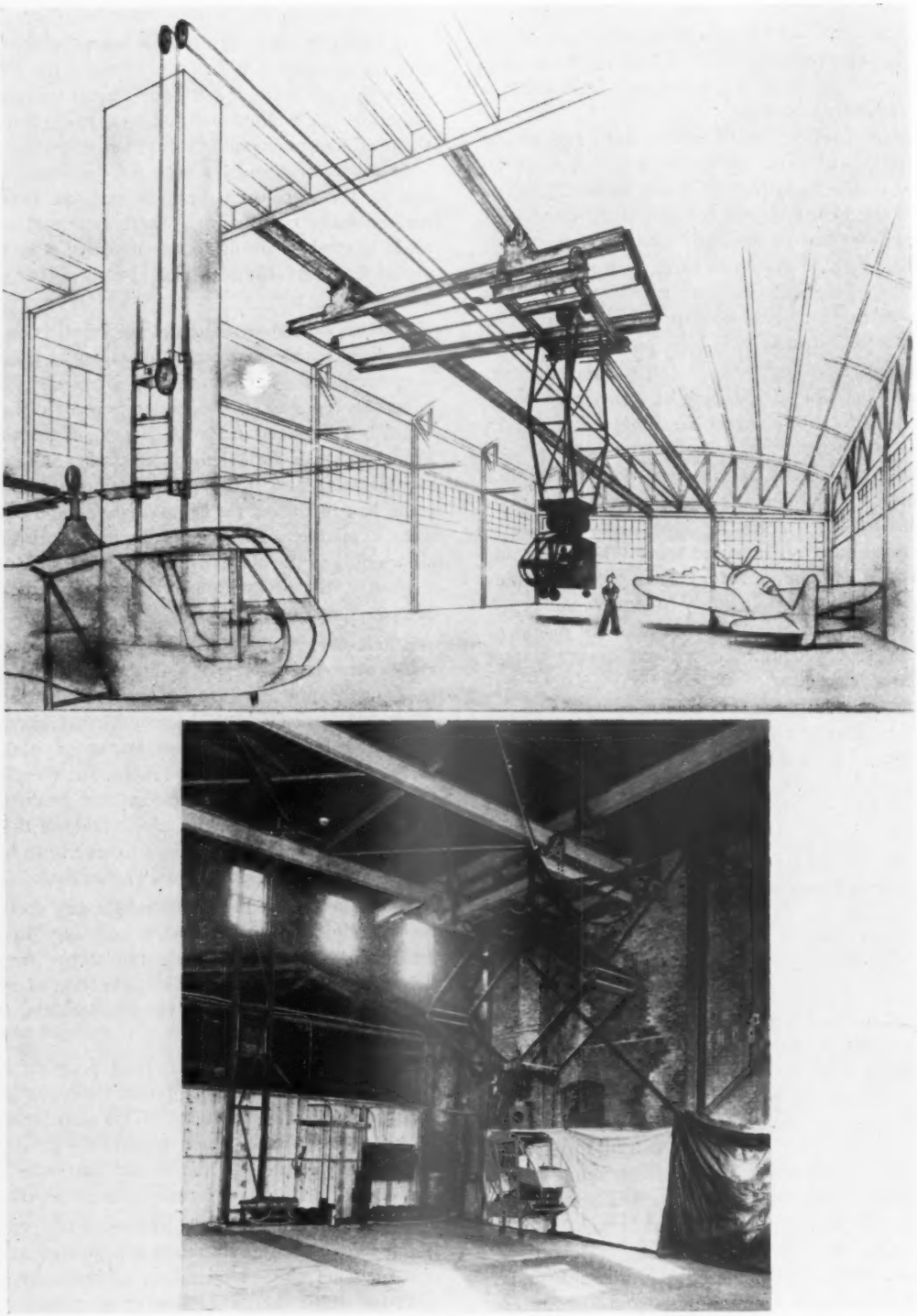

FIG. 1.

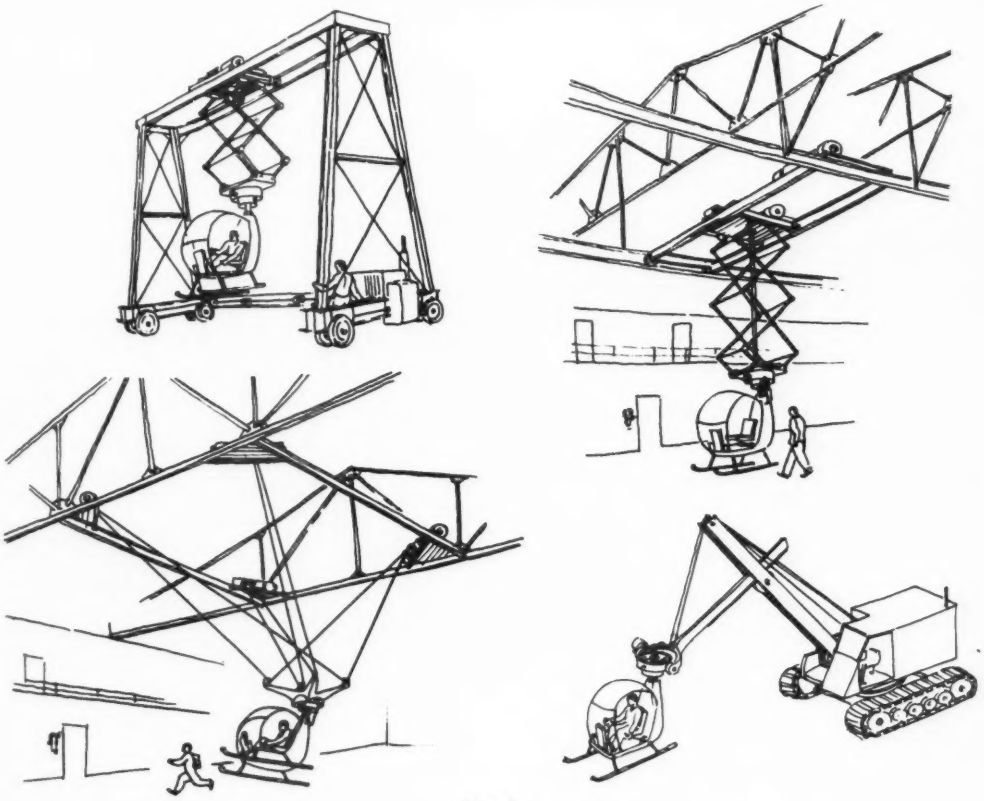

FIG. 2.

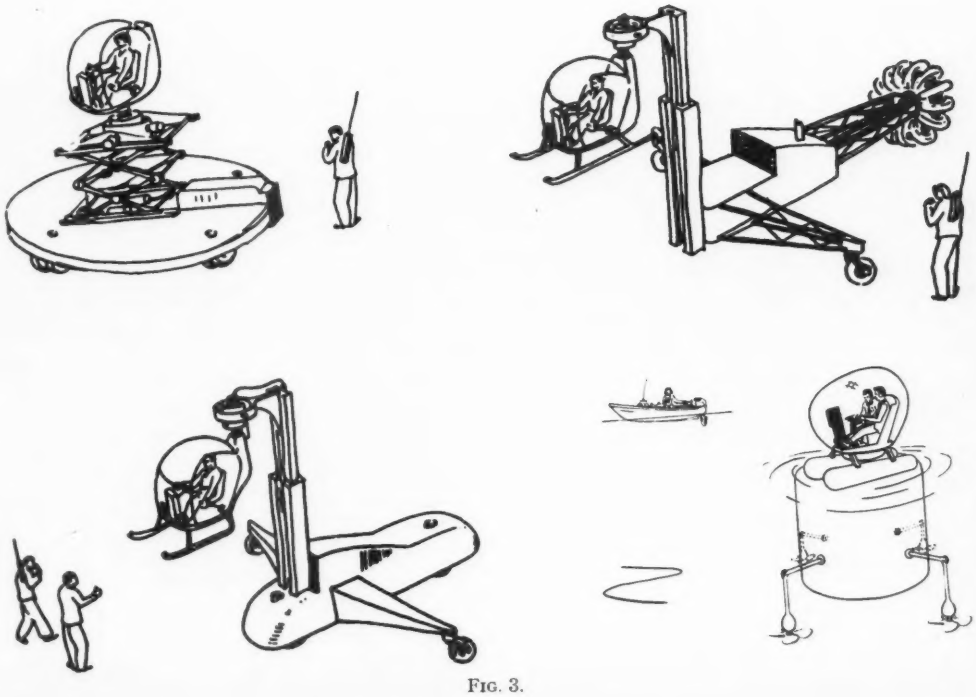

FIG. 3.

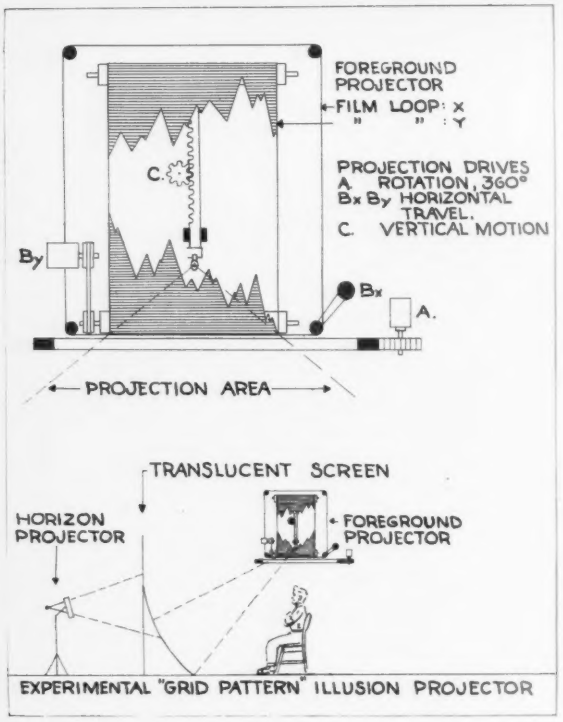

FIG. 4.

stressed—such as the ability to isolate or exaggerate certain operational characteristics.

(3) The consideration of a wide variety of possible equipment to permit the choice of a type of device and a configuration which would best satisfy the training tasks and functional requirements already established. Such a choice is a complex matter since no one device could have all the advantages, and it becomes a question of making the best horse trade possible between complexity to secure accuracy and ability to do a satisfactory job of training students.

Experience has shown that the approach outlined produces the necessary perspective to evolve a training device functionally and economically tailored to the training task. To consider this problem as merely one of achieving the complete and accurate simulation of operational conditions—such as aircraft flight—will usually result in a device which is more elaborate and expensive than is necessary and, in some cases, may even fail to produce an effective trainer.

The study of the training task revealed that student helicopter pilots would be drawn from already qualified fixed-wing pilots, for, although it may take a relatively short time to impart the manual skill required for flight in a specific type of aircraft, it takes a long time to make a competent airman. Many hours of flying are required to apply the knowledge learned concerning navigation, atmospheric conditions, communications, etc., and to develop air sense—sound judgment and decisiveness—which can only be achieved as a result of actual flight experience.

To gain such experience in helicopters alone would require more machines than are available and would involve much greater maintenance and cost. Consequently, the training problem resolved itself into "converting" fixed-wing pilots to helicopter flight techniques rather than furnishing complete basic air training.

To the fixed-wing pilot, the helicopter is relatively easy to fly in straight and level flight, but he finds it difficult to accustom himself to slow speed close to the ground and landings. To acquire the skills needed for hovering and near hovering flight, many hours of practice are required. In hovering, all the forces acting on the helicopter must be maintained in balance, although flight conditions vary, and even the slightest air current will disturb equilibrium. Therefore, during hovering and near hovering flight, the pilot is forced to use both hands and both feet in virtually continuous control activity. In take-offs and landings, he goes through a brief hovering stage and later is required to develop the ability to hover and pick up personnel and cargo.

It followed that the first objective of a synthetic training device for helicopter flight should be to provide student pilots with the practice necessary to master the coordination of all controls in hovering. These hours are a vital part of the conversion of a qualified fixed-wing pilot and airman into a competent helicopter pilot.

Thus, it remained to establish the functional requirements of a hovering trainer, starting with the study and listing of the various cues which a helicopter pilot uses in hovering. This phase of the study indicated that the most important cues were visual, which was confirmed by pilots who achieved control in hovering by visual observation of the attitudes and motions of the helicopter with respect to terrain. In addition, it was apparent that a limited number of instrument indications furnished useful cues in hovering—such as r.p.m. of engine and rotor, manifold pressure as a gage of power output, and other indirect and secondary cues including awareness of engine and rotor noise and vibration.

Suprisingly enough, the kinesthetic cues provided by roll, pitch, vertical accelerations, etc., appeared to be of relatively little importance to the pilot in hovering. This finding was confirmed by wide sampling of pilot opinion and experimentally by the "blindfold" observation and analysis of flight attitudes and motions by an observer. This conclusion, incidentally, provides a graphic illustration of the importance of analyzing the training problem generally before thinking specifically in terms of equipment, since in the early consideration of the problem it appeared necessary and desirable to include roll and pitch in the cockpit. Actually, inclusion of these motions in the final device would have contributed relatively little to training value but would have added substantially to the complexity and cost of the final device.

At this point, it was possible to formulate the many functional requirements for a proposed helicopter hovering trainer, including the establishment of the general level of complexity which would be needed for hovering training and the degree of visual simulation required.

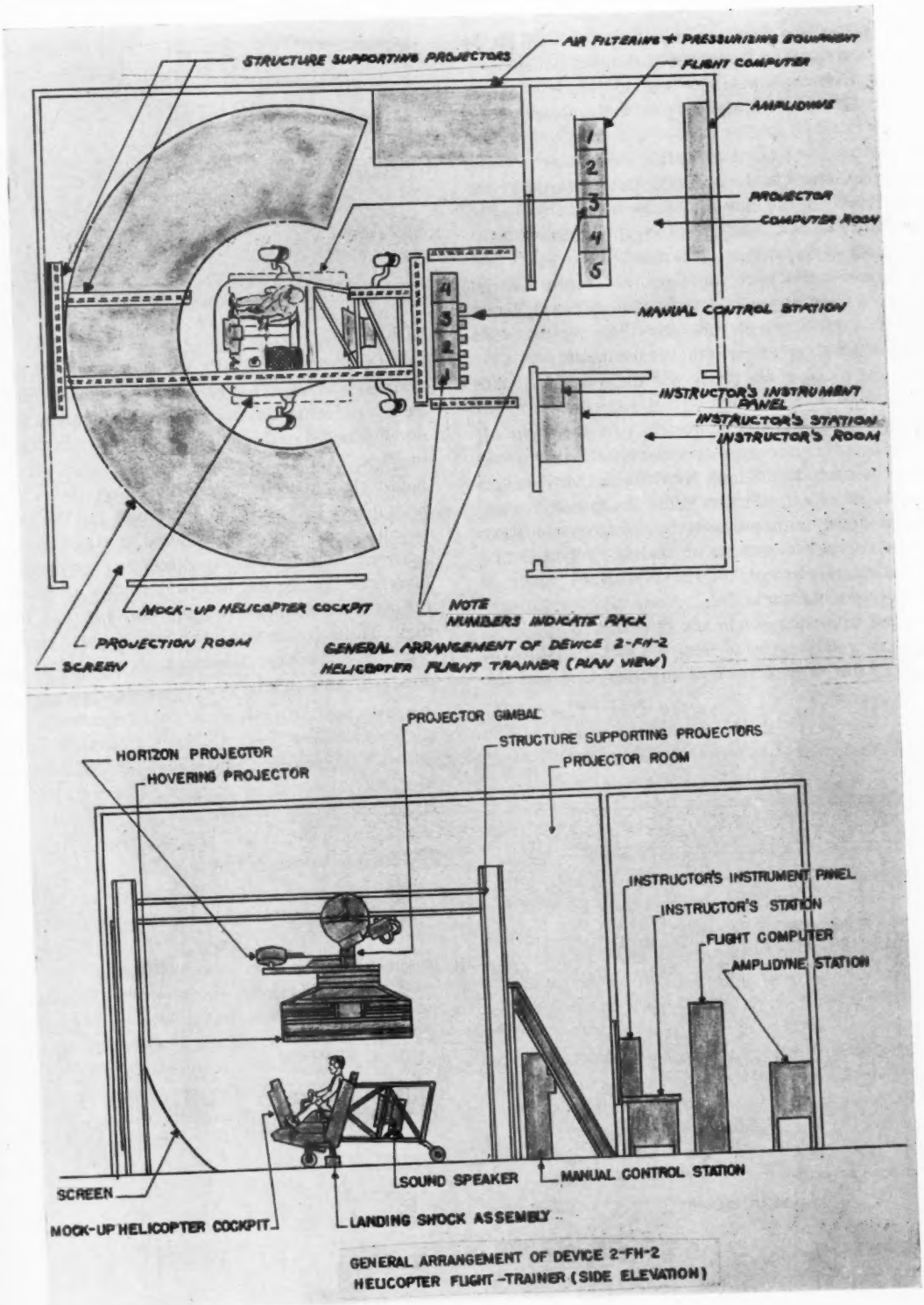
STRUCTURE SUPPORTING PROJECTORS
AIR FILTERING + PRESSURIZING EQUIPMENT
FLIGHT COMPUTER
AMPLIDYNE
PROJECTOR
COMPUTER ROOM
MANUAL CONTROL STATION
INSTRUCTOR'S INSTRUMENT PANEL
INSTRUCTOR'S STATION
INSTRUCTOR'S ROOM
MOCK-UP HELICOPTER COCKPIT
NOTE NUMBERS INDICATE RACK
PROJECTION ROOM
SCREEN
GENERAL ARRANGEMENT OF DEVICE 2-FH-2 HELICOPTER FLIGHT TRAINER (PLAN VIEW)
PROJECTOR GIMBAL
STRUCTURE SUPPORTING PROJECTORS
HORIZON PROJECTOR
HOVERING PROJECTOR
PROJECTOR ROOM
INSTRUCTOR'S INSTRUMENT PANEL
INSTRUCTOR'S STATION
FLIGHT COMPUTER
AMPLIDYNE STATION
SCREEN
SOUND SPEAKER
MANUAL CONTROL STATION
MOCK-UP HELICOPTER COCKPIT
LANDING SHOCK ASSEMBLY
GENERAL ARRANGEMENT OF DEVICE 2-FH-2 HELICOPTER FLIGHT-TRAINER (SIDE ELEVATION)

FIG. 6.

Certain minimum requirements were established for the visual display—angular coverage, perspective, three-dimensional effects to aid altitude estimation, etc.—which were considered important, not only to provide flight cues but also to create the illusion of flight in the mind of the average student with limited imagination and receptivity. Simulation beyond this level, however, would make the device needlessly complex and costly.

At the same time, the relative importance of the various requirements was also established, including the broad division of the cues into those which are vital to flight and those which aid in creating an illusion of flight in the mind of the student. It should be stressed that these requirements were functional in nature and did not imply a specific type of device; they did imply, however, that a device which met only these requirements would constitute an efficient device for its purpose.

The next phase of the study was the consideration of various types of equipment and devices which might fulfill the established requirements. At this point, it was necessary to encourage creative uninhibited thinking of a number of different minds to arrive at a specific concept. Even schemes which in themselves appeared obviously impractical were given consideration, for often a successful scheme ultimately evolves from a combination of elements of other schemes which in themselves are not workable.

The first approach lay in the direction of the "real motion" or vehicle type of device which had the advantage of direct simulation of flight motion and the benefit of experience with the World War II helicopter trainer, which was developed under the direction of the authors. Many different possible schemes were studied and evaluated in this category, a few of which are shown in Figs. 2 and 3 (see also Appendix). There is little doubt that a useful device based on the real motion principle could have been developed, but the evaluation of all such devices considered brought out serious inherent disadvantages—excessive requirement for hangar or ramp space, lack of flexibility for future adaptation to instrument training and broader ranges of flight, limited operating flexibility, and high construction cost to reproduce helicopter dynamics in view of greater masses involved.

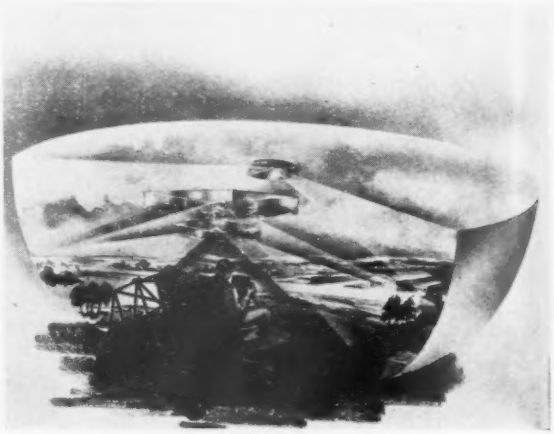

FIG. 8.

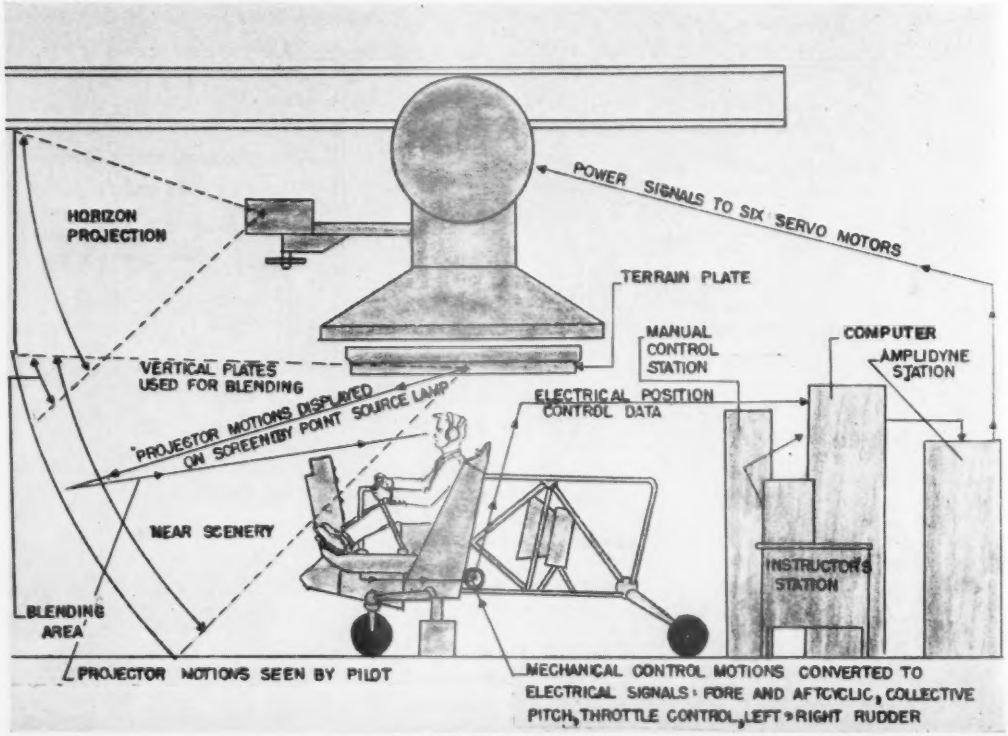
HORIZON PROJECTION
POWER SIGNALS TO SIX SERVO MOTORS
TERRAIN PLATE
MANUAL CONTROL STATION
COMPUTER
AMPLIDYNE STATION
VERTICAL PLATES USED FOR BLENDING
PROJECTOR MOTIONS DISPLAYED ON SCREEN BY POINT SOURCE LAMP
ELECTRICAL POSITION CONTROL DATA
NEAR SCENERY
INSTRUCTOR'S STATION
BLENDING AREA
PROJECTOR MOTIONS SEEN BY PILOT
MECHANICAL CONTROL MOTIONS CONVERTED TO ELECTRICAL SIGNALS: FORE AND AFT CYCLIC, COLLECTIVE PITCH, THROTTLE CONTROL, LEFT-RIGHT RUDDER

FIG. 7. Information flow.

These considerations led to the conclusion that the most practical solution lay in the "illusion" type of device in which the cockpit is stationary and the appearance of motion is created by optical projection. This eliminates the movement of large masses and gives greater scope to the device, but there remained the great problem of creating the illusion of flight with sufficient realism to serve the purpose.

After considerable research and experiment, it was found that an adequate illusion of motion could be created with relatively inexpensive optical components by recourse to the "point source" projection technique. This system is based on the principle that, if a small but intense light source is projected through a transparency, it is possible to obtain a sharp image of the scenery or markings on the transparency when reflected on a screen. This technique has the further advantages of providing a very wide angle of projection and making possible a completely nonprogrammed display which is inherently necessary for the pilot and rules out filmed flight simulation projection.

The first working model did not attempt to project real scenery but consisted of a point source of light projecting a variable image on a horizontal screen through two endless transparent belts, oriented 90° apart, each of which was ruled with opaque lines. The resulting projection was a "checkerboard" pattern whose motion and size combined to create an illusion of horizontal and vertical motion. The individual motions of the two belts represented the two components of horizontal motion of the aircraft, and thus a resultant apparent motion in any direction was conveniently obtained. Yawing motion was obtained by rotating the belts and light source as a unit, and altitude changes were achieved by vertical motion of the light source. The projection obtained was supplemented by a rear-projected, distant horizon scene which provided the horizon reference for attitude observation. (See Fig. 4 and Appendix.)

This experimental device, although relatively crude, was sufficiently good to prove that an adequate illusion of flight could be synthetically created by a comparatively simple projection means, and it is entirely possible that a grid or spot pattern of this type may be adequate for primary hovering training. It is to be hoped that additional investigation will be pursued along these lines since the scheme has one major advantage for certain training purposes—the endless belts permit unlimited horizontal travel in any direction.

As a result of the tests on this experimental device, it was concluded that a hovering trainer of the illusion type was feasible and could be designed and produced at reasonable cost. It was further concluded that this type of device would be best suited to the training task and, at the same time, comply with the mobility requirements imposed by the training establishment. Accordingly, work proceeded into the actual design stage which has resulted in a device in which the pilot flies over realistic terrain in a 400-ft. circle with distant horizon and at altitudes from the ground to 50 ft.

This program, now successfully completed, involved many different fields of engineering and required a major amount of development and design work. A substantial research program was required to perfect the point source projection technique to achieve the illusion considered necessary for the prototype, providing a wide angle, nonprogrammed, three-dimensional scenic display. Intricate mechanical and servo designs were required in order to move the projection elements smoothly and at correct rates and with realistic response characteristics. A set of flight equations suitable for the hovering training application had to be derived; it was important that these equations be realistic enough to provide a reasonable simulation of helicopter flight and yet simple enough to permit design and construction of a reasonably inexpensive analog computer. (See Tables 1, 2, 3, and Appendix.)

Throughout the development and design stages of the project, every attempt was made to bear foremost in mind that the device and its components should be tailored to the originally established philosophy which summarized the training tasks and requirements of the device. The primary criterion was always the effect on training value for the student rather than achievement of a greater intrinsic degree of simulation. This same philosophy applied to the necessary simplification of the equations of flight; the equations were in every case simplified to the point believed to be the minimum level of complexity which could provide satisfactory hovering training.

The final device, now completed, can be described briefly as follows. Photographs and diagrams which illustrate the device are included in Figs. 5*–8 (see also Appendix). The principal components are projection system, cockpit, and computer. The projector and its associated screen present to the pilot a visual picture of the surrounding terrain, and the illusion of all motions of the helicopter is created by the motions of the projector. The cockpit is an actual helicopter cockpit with all controls and certain instruments operative. It is provided with limited dynamic landing effects and characteristic noise and vibration in proportion to throttle setting.

The function of the computer is to receive electrical signals from the pilot's controls, introduce them along with certain fixed inputs into the equations of motion of the helicopter, and provide proper output signals to the projector servos, which in turn simulate the motions that would occur in the helicopter in response to similar control activity.

The overall arrangement of the components of the device is illustrated in Fig. 6. Shown on this illustration are the projector, cockpit, computer, power servos, and instructor's station. The projector and its surrounding screen, with the cockpit at the screen center, form the basic enclosure. Shown outside the enclosure are the

* Fig. 5, headpiece, p. 114.

TABLE 1
Computer Equations

FOR $H-H_G>0$ AND $T \geqq W$

AND FOR $H-H_G=0$ AND $T \geqq W$

$$\dot{u} = -\frac{g}{W}(Ta_{1S} + W\textcircled{H} + D_{f_1}) \quad (1)$$

$$u_1 = \int \dot{u}_1\, dt \quad (2)$$

$$\dot{w}_1 = \frac{g}{W}(W\Phi - Ta_{2S} - D_{f_2} + T_T) - u_1 r \quad (3)$$

$$w_1 = \int \dot{w}_1\, dt \quad (4)$$

$$\dot{w}_T = \frac{g}{W}(W - T) \quad (5)$$

$$w_T = \int \dot{w}_T\, dt \quad (6)$$

$$\dot{p} = \frac{Tha_{2S} - T_T h_T - \frac{1}{12} W c g_2}{I_X} \quad (7)$$

$$p = \int \dot{p}\, dt \quad (8)$$

$$\dot{q} = \frac{Tha_{1S} + M_f - .125\, W c g_1}{I_Y} \quad (9)$$

$$q = \int \dot{q}\, dt \quad (10)$$

$$\dot{r} = \frac{Q_R - T_T \ell - N_T \cdot r + N_{w_1} \cdot v}{I_Z} \quad (11)$$

$$r = \int \dot{r}\, dt \quad (12)$$

$$D_{f_1} = k_{D_1} u_1 \quad (13)$$

$$D_{f_2} = k_{D_2} v_1 \quad (14)$$

$$M_f = f_1(u_1) \quad (15)$$

$$a_{1S} = a_1 + \phi_1 \quad (16)$$

$$\phi_1 = \theta_1 + P c_1 \quad (17)$$

$$q + c_1 = -G c_1 \quad (18)$$

$$a_1 = k_Q u_1 \quad (19)$$

$$a_{2S} = a_2 + \phi_2 \quad (20)$$

$$\phi_2 = \theta_2 + P c_2 \quad (21)$$

$$-p + \dot{c}_2 = -G c_2 \quad (22)$$

$$a_2 = k_Q v_1 \quad (23)$$

$$c_1 = \int \dot{c}_1\, dt \quad (24)$$

$$c_2 = \int \dot{c}_2\, dt \quad (25)$$

$$T_\infty = \rho k_T \Omega^2 [\theta_0 + f_2(u_1) + k'_T u_1 a_{1S}] \quad (26)$$

$$T = T_\infty \cdot f_1(H \cdot H_G) \cdot f_3(u_1) \quad (27)$$

$$Q_R = \rho k_Q \Omega^2 [k_1 + k_2 \theta_0 + k'_Q u_1 a_{1S}] \quad (28)$$

$$T_T = k_{T_T} \Omega^2 \theta_T \quad (29)$$

$$Q_T = k_{Q_T} \Omega^2 [k_3 + k_4 / \theta_T] \quad (30)$$

$$\Omega = \frac{550\, BHP}{Q_R + k_S \cdot Q_T} \quad (31)$$

$$BHP = (MP - 5)\left(\frac{\partial BHP}{\partial MP}\right)_N \cdot \frac{\rho}{\rho_0} \quad (32)$$

$$\left(\frac{\partial BHP}{\partial MP}\right)_N = f_1(N) \quad (33)$$

$$MP = f_1(H_-) + N(1 - H_-) f_2(N) \quad (34)$$

$$\Phi = \int p\, dt \quad (35)$$

$$\textcircled{H} = \int q\, dt \quad (36)$$

$$\dot{\psi} = r - p\textcircled{H} + q\Phi \quad (37)$$

$$\psi = \int \dot{\psi}\, dt \quad (38)$$

$$V_N = (u_1 + u_{1_\textcircled{H}}) \cos\psi - (v_1 - w_{1_\Phi}) \sin\psi \quad (39)$$

$$V_E = (u_1 + u_{1_\textcircled{H}}) \sin\psi + (v_1 - w_{1_\Phi}) \cos\psi \quad (40)$$

$$V_V = -u_1\textcircled{H} + v_1\Phi + w_1 \quad (41)$$

$$\epsilon(V_V) = V_V - V_{V'} \quad (42)$$

$$V_{NG} = V_N - V_W \cos\psi_W \quad (43)$$

$$\epsilon(V_{NG}) = V_{NG} - V_{NG'} \quad (44)$$

$$V_{EG} = V_E - V_W \sin\psi_W \quad (45)$$

$$\epsilon(V_{EG}) = V_{EG} - V_{EG'} \quad (46)$$

$$N = k_6 \Omega \quad (47)$$

$$H = -\int V_V\, dt \quad (48)$$

$$\textcircled{H}_S = -\textcircled{H} \quad (49)$$

$$\epsilon(\textcircled{H}_S) = \textcircled{H}_S - \textcircled{H}_S' \quad (50)$$

$$\Phi_S = -\Phi \quad (51)$$

$$\epsilon(\Phi_S) = \Phi_S - \Phi_S' \quad (52)$$

$$\psi_S = -\psi \quad (53)$$

$$\epsilon(\psi_S) = \psi_S - \psi_S' \quad (54)$$

$$IAS = 0.682 u_1 \quad (55)$$

$$\rho = 0.00268 - 0.0000048t \quad (56)$$

$$H_G = H_{GN} \cdot H_{GE} \quad (57)$$

$$V_{gy} = v_1 - V_W \sin(\psi - \psi_W) \quad (58)$$

FOR $H-H_G=0$ AND $T<W$ ABOVE EQUATIONS REMAIN UNCHANGED EXCEPT FOR THE FOLLOWING

$$D_{f_1} = k_{Dg} u_1 \quad (59)$$

$$D_{f_2} = k_{Dg'} v_1 \quad (60)$$

$$w_1 = 0 \quad (61)$$

$$\Phi = p = 0 \quad (62)$$

$$\textcircled{H} = q = 0 \quad (63)$$

$$r = 0 \quad (64)$$

$$V_W = 0 \quad (65)$$

FOR ANY VALUE OF $H-H_G$ AND OF $T-W$ WHEN THE "FREEZE" SWITCH IS TURNED "ON" THE COMPUTER SHALL MAKE EACH OF THE FOLLOWING QUANTITIES EQUAL TO ZERO

a) $\dot{u}_1$ d) V_{NG} g) $\dot{\Phi}_S$

b) $\dot{\Omega}$ e) V_{EG} h) $\dot{\psi}$

c) V_V f) $\dot{\textcircled{H}}_S$

TABLE 2
Equation Symbols

TABLE 2

Equation Symbols

a_1 - blade flapping coefficient, equals angle of inclination of tip path plane intersection with xz-plane due to forward velocity u_1, positive when u_1 is positive, in radians.

a_2 - blade flapping coefficient equals angle of inclination of tip path plane intersection with yz-plane due to lateral velocity v_1, positive when v_1 is positive, in radians.

a_{1s} a_{2s} - angles representing inclination of tip path plane intersection relative to x- and y- axes, respectively, positive when front and right sides of rotor are up, in radians.

BHP - brake horsepower of engine

C_1, C_2 - inclination of stabilizer bar plane relative to x and y-axes, positive when front and right sides are up, in radians

CG_1 - longitudinal c.g. position from neutral, positive forward, in inches

CG_2 - lateral c.g. position from neutral, positive to right, in inches.

D_{f_1} - fuselage drag in x direction, positive when u_1 is positive, lbs

D_{f_2} - fuselage drag in y direction, positive when v_1 is positive, lbs.

$f_1(H-H_G)$ - empirical function which represents "ground effect" on main rotor thrust

$f_1(MP)$ - arbitrary function introduced to increase power absorbed by rotor system in the low power region.

$f_1(N)$ - function representing the change in BHP with MP at different engine RPM.

$f_2(N)$ - empirical function used to determine change in manifold pressure with engine RPM at different throttle settings.

$f_1(\%)$ - function representing basic manifold pressure variation with throttle setting.

$f_1(u_1)$ - arbitrary aerodynamic pitching moment function to give correct stick position vs. airspeed characteristic.

$f_2(u_1)$ - arbitrary function selected to give proper power vs airspeed characteristic.

$f_3(u_1)$ - arbitrary function selected to decay "ground effect" as forward velocity increases.

g - acceleration due to gravity, ft./sec.^{2}

G - stabilizer bar following rate equals 15.65 rad./sec / rad.

h - vertical distance of rotor hub above center of gravity equals 4.93 ft.

h_T - vertical distance of tail rotor hub above x-axis, in feet.

H - altitude of wheels above sea level, ft

H_G - altitude of ground above sea level, ft

H_{GN}, H_{GE} - components of ground altitude on the North and East directions as measured on the projection plate.

IAS - indicated air speed, mph

I_x, I_y, I_z - moment of inertia of helicopter about x, y, z axes, slug ft.^{2}

ℓ - distance from center of gravity to hub of tail rotor, ft.

k_1, k_2 - dimensionless constants used in main rotor torque calculation

k_3, k_4 - dimensionless constants used in tail rotor torque calculation

k_5 - gear ratio tail to main rotor

k_6 - constant to convert engine RPM through gear ratio to rotor velocity in radians/sec.

k_a - rotor flapping coefficient factor, radian - sec./ft.

k_{D1} - fuselage drag coefficient, x direction, lb.-sec./ft.

k_{D2} - fuselage drag coefficient, y direction, lb.-sec./ft.

k_{Dg} - ground drag coefficient, x direction, lb.-sec./ft.

$k_{D\dot{g}}$ - ground drag coefficient, y direction, lb.-sec./ft.

k_Q - main rotor torque coefficient, ft.^{5}

$k_{Q'}$ - constant used in main rotor torque calculation.

k_{QT} - tail rotor torque coefficient, lb.-ft.-sec.^{2}

k_T - main rotor thrust coefficient, ft.^{4}

$k_{T'}$ - constant used in main rotor thrust calculation

k_{T_T} - tail rotor thrust coefficient, lb.-sec^2

M_f - fuselage pitching moment, positive nose up, lb.-ft

MP - manifold pressure, inches of mercury

N - engine RPM

N_r - yawing moment due to yawing velocity, lb.-ft-sec

N_{v_1} - yawing moment due to lateral velocity, lb.-sec

p - rolling velocity about x axis, positive right side down, rad./sec.

q - pitching velocity about y axis, positive nose up, rad./sec.

r - yawing velocity about z axis, positive nose right, rad./sec.

P - percent of stabilizer bar tilt affecting cyclic pitch, equals 0.76.

Q_R, Q_T - torque of main and tail rotor, pound-ft.

t - temperature in °F

T, T_T - thrust of main and tail rotors, positive up and to the right, respectively, pounds

T_{oe} - thrust of main rotor out of ground effect, lbs.

%A - percent throttle opening.

u_1 - velocity of center of gravity in x direction, positive forward, ft./sec.

v_1 - velocity of center of gravity in y direction, positive to right, ft./sec.

w_1 - velocity of center of gravity in z direction, positive down, ft./sec.

V_N, V_{NG} - computed north horizontal component of air speed and ground speed, respectively, ft./sec.

V_E, V_{EG} - computed east horizontal component of air speed and ground speed, respectively, ft./sec.

$V_{\dot{y}}$ - lateral ground velocity, ft./sec.

V_{NG} V_{EG} - measured north and east components of ground speed, ft./sec.

V_{w} - computed vertical component of air speed, positive down, ft./sec

$V_{w'}$ - measured vertical component of air speed, ft./sec.

V_{wg} - ground wind velocity magnitude, ft./sec.

W - helicopter gross weight, pounds

x, y, z - reference body axes, original at center of gravity, x positive forward, y positive to right, z along rotor mast positive down.

$\epsilon(\ )$ - error between computed and measured values of quantity specified in parenthesis.

θ_0 - collective pitch angle of main rotor blades, radians.

θ_1, θ_2 - inclination of swash plate plant relative to x and y axes, positive when front and right sides are up, radians.

θ_T - collective pitch of tail rotor blades, radians.

θ - angle between x-axis and horizontal plane measured in vertical plane, positive nose up, radians.

θ_s - computed scenery projection plate pitch angle, positive front up, radians.

θ_s' - measured values of scenery pitch angle, radians.

ρ - air density, slugs/ft.^{3}

ϕ_1, ϕ_2 - inclination of control plane (plane of no feathering) relative to x and y axes, positive when front and right sides are up, radians.

ϕ - angle between y-axis and horizontal plane measured in plane perpendicular to the x-axis, positive right side down, radians.

ϕ_s - computed scenery projection plate roll angle, positive right side down, radians

ϕ_s' - measured value of scenery roll angle, radians.

ψ - angle between north and vertical plane containing x-axis measured in horizontal plane, positive nose clockwise from north when viewed from above, radians.

ψ_s, ψ_s' - computed and measured angle between north on scenery projection plate and longitudinal axis of trainer room, positive clockwise from room axis when viewed from above, radians

ψ_w - angle representing direction from which wind blows, positive clockwise from north, radians.

Ω - main rotor angular velocity, radians/sec.

TABLE 3
Range of Variables

$a_{1S} = a_{2S} = \pm 0.131$ RAD	$u_1 = \pm 15$ FT/SEC
$C_1 = C_2 = \pm 0.087$ RAD	$V_N = V_E = \pm 60$ FT/SEC
$CG_1 = +2.00"$ TO $-2.88"$	$V_{NG} = V_{EG} = \pm 60$ FT/SEC
$CG_2 = \pm 1.5"$	$V_W = \pm 15$ FT/SEC
$H = 0$ TO 90 FT	$V_{W'} = 0$ TO $+22$ FT/SEC
$H_G = 0$ TO 20 FT	$W = 1800$ TO 2400 LBS
IAS $= -10$ TO $+41$ MPH	$\theta_0 = +0.015$ TO $+0.192$ RAD
MP = 10 TO 29 INCHES Hg	$\theta_1 = \pm 0.128$ RAD
$N = 1600$ TO 3200 RPM	$\theta_2 = +0.113$ TO -0.085 RAD
$\dot{p} = \dot{q} = \dot{r} = \pm 1.2$ RAD/SEC^2	$\theta_T = +0.148$ TO -0.085 RAD
$p = q = r = \pm 1.0$ RAD/SEC	$\textcircled{H} = \textcircled{H}_S = \pm 0.384$ RAD
$t = 0$ TO 100°F	$\rho = 0.00268$ TO 0.00220 SLUGS/FT^3
$H_h = 0$ TO 1.0	$\Phi = \Phi_S = \pm 0.384$ RAD
$\dot{u}_1 = \dot{v}_1 = \dot{w}_1 = \pm 10$ FT/SEC^2	$\dot{\psi} = \pm 1.0$ RAD/SEC
$u_1 = -15$ TO $+60$ FT/SEC	$\psi = \psi_S = \pm$ CONTINUOUS ROTATION
$v_1 = \pm 30$ FT/SEC	$\psi_W = \pm$ CONTINUOUS ROTATION
	$\Omega = 18.6$ TO 38.0 RAD/SEC

computer cabinets, the instructor's station, racks for mounting the motor generator sets of the power servos, and a manual control station provided to mount miscellaneous electrical equipment as well as controls for manual operation of the power servos.

Fig. 7 is a simplified flow diagram of the above units which shows the nature and direction of information flow. The basic inputs to the system are the pilot's movements of the helicopter controls. These mechanical control motions are converted into electrical signals which in turn are fed into the computer. The computer introduces this control position information, along with various preset data such as wind, loading conditions, air temperature, etc., into the flight equations and produces output signals corresponding to the motions the helicopter would achieve when subjected to the same control activity. These output signals control the six motions of the projection system which correspond to the six degrees of freedom of the aircraft. In addition, signals are provided to control engine noise, vibrations, landing effect, and instrument indications. Thus the system is an open loop with the pilot himself the means of closing the loop.

The above description covers generally the device and its major elements. A detailed description of the numerous research and design problems which had to be solved will not be included since the main objective of this paper is to stress primarily the study and analysis which evolved the device rather than the details of the device itself. The more detailed aspects of the device and many of the unusual design problems encountered during its development have been adequately covered in a paper by T. J. Harriman of the Bell Aircraft Corporation before the American Helicopter Society in April, 1955. His paper includes a discussion of the design and test treatment given to such specialized problems as the projector power servo drives and their associated worm gearing, as well as discussion of the problems encountered in extending the use of the device to training in autorotation procedures.

Appendix

Fig. 1 includes a photograph of the helicopter flight trainer developed in 1943–44 under the direction of the authors and also an artist's sketch of the device installed in its hangar. The device consists of a single seat cockpit with controls and instruments suspended from an overhead crane structure. The cockpit is suspended immediately below a pitch and roll gimbal assembly which in turn is suspended from a rotating gimbal for providing yaw. The pantagraph and cable device lifted the cockpit to an altitude of about 10 ft. Correct direction of horizontal motion was obtained by resolving the instantaneous velocity vector into components across the crane bridge and longitudinally along the main crane rails. All drives were d.c. motors utilizing a Ward-Leonard control system, and the computing devices were all-mechanical. No space was provided in the cockpit for an instructor, but repeater instruments facing outward were included with the cockpit.

Figs. 2 and 3 illustrate various schemes considered in the study of "real motion" types of devices. Fig. 2 includes three possible approaches based on the overhead suspension principle and also shows a scheme patterned after a conventional steam shovel. The cockpit is suspended at the end of the boom system, free to tilt and rotate about its suspension. Vertical and horizontal motions are provided by the actions of the booms and the caterpillar treads. Fig. 3 shows a series of vehicle type of devices which were studied. These schemes all contemplate travel over the ground or on a concrete ramp. Also shown is a water-borne type of device.

Fig. 4 illustrates in sketch form the "crossed belt" type of illusion projector described in this paper.

Figs. 5, 6, 7, and 8 are photographs and artist's sketches illustrating the helicopter flight trainer which was developed as a result of the study described in this paper.

Tables 1, 2, and 3 show equations and data used in the analog computer in the flight trainer. Table 1 presents the basic equations of flight used in the device; Table 2 explains the symbols used in these equations; and Table 3 shows the ranges of variables. It should be noted that these equations and data are presented here to illustrate the approach used and are the original equations derived. As expected, some changes in constants were necessary during the test phase, but no major changes were required.

The Impact of Electronic Equipment on Electric Generator Design . . .

(*Continued from page 93*)

(4) There is the consideration for the change, if any, in the c.g. position and the effect or compensation necessary in the aircraft.

These factors, together with any provisions made for the aspiration of the engines when they are installed inside the aircraft, make the use of GTPU's and GTC's less attractive as a complete accessory power installation. Their use as emergency, back-up, or supplementary units, however, still remains attractive.

Conclusions

If any conclusions at all can be drawn from this paper, one of them is certainly that there is no panacea for the provision of accessory power in aircraft. The growth of electronic systems alone has greatly affected the trend of development of accessory drives and power, and, in its further ramifications, the increasing power demand and weight of the electronic system have had impact not only on the performance of the engines but on the performance of the aircraft itself.

Typical examples of aircraft whose prime function is to carry electronic equipment are the radar early warning aircraft and the ASW types. Other aircraft, whose mission and function are completely allied to the electronic system, are the present series of high performance long/short-range interceptors, attack bombers, and long-range bombers, whose complex electronic systems are used for navigation, search/detection, automatic fire control, and bombing.

These aircraft, and those now in the design stage, place so much importance on the electric power generation system and the electronic systems that the integration of these systems into the airplane is imperative at a very early stage in order that the overall weapon system may be optimized.

Guest Editorial—Electronics in Aviation

(*Continued from page 57*)

instrumentation, I am reminded of a story about a farmer who was asked to buy an encyclopedia. When informed that the encyclopedia contained practically all of mankind's knowledge, he said, "No, I don't want it. I already know more than I can use."

It is a natural reaction for the aeronautical engineer who knew and loved the relatively simple aircraft of the past to be seriously perturbed by the reliability, the complication, the weight, the size, the high power consumption, and the increasing cost of this array of electronic equipment. Yet it is generally accepted that the recent great improvements in the classical aeronautical performance factors such as range, speed, altitude, etc., could not have been gainfully used in military aircraft without the aid of modern electronic devices. A few failures to accept this point of view have resulted in relatively ineffective designs. This statement, however, does not imply that engineering exercises to reduce unwanted redundancy and unnecessary complication will not pay off in both improved performance and increased reliability.

If there is one clear need in the aeronautical engineering field today, it is for the creative aircraft designer who is as firmly grounded in the fields of electronics and instrumentation as in the traditional aircraft engineering fields of propulsion, aerodynamics, structures, etc. Such designers, backed up by a multitude of specialists, can get the most out of the high-performance aircraft possibilities of tomorrow.

There is another vast field of electronics in aviation consisting of the ground radar tracking and navigational environment. Some of the elements of this environment are ground detection and tracking radars, transmitter and transponder components of either beam or grid navigational systems, beacons, radio communications, electronic computers, and plotting boards. In the military field, the radar detection, warning, and ground control of interception network is a key element in air defense; in the civil transport field, air-lane traffic control and terminal landing and take-off instrumentation are limiting elements in the utilization of air transport capabilities. Both of these systems have overlapping functions and capabilities, and both must undergo vast change and improvement as the performance of military aircraft improves, as the number of civil aircraft increases, and as commercial jet liners are introduced. In this field of electronics, improved component performance is not critical. It is rather the system design for flexibility and reliability, to suit the many needs, which is controlling. Again, we find that the principal engineering personnel requirement is for the engineer with the breadth of understanding of the many factors which influence these systems designs.

In both of these fields of "Electronics in Aviation," the electronics in the aircraft and the electronic environment, the accent must be on the "in Aviation" part.

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CORPORATE MEMBER NEWS

• **Aerophysics Development Corporation,** of Santa Monica, Calif., has purchased a 104-acre tract in Santa Barbara and will construct a $1,300,000 research plant there for occupancy in September. Plans call for an engineering building with 56,120 sq. ft. of floor space and a research building with 55,000 sq.ft. The company, which is a subsidiary of Studebaker-Packard Corporation, will move to Santa Barbara.

• **Airborne Accessories Corporation** announces the appointment of Nat Cancilla as Chief Engineer. He was formerly Director of Engineering of Associated Engineers, Inc.

• **American Airlines, Inc.,** increased its air freight business by 24 per cent in 1955 and set new monthly records for domestic air lines during 6 months in which the scheduled air freight exceeded 6,000,000 ton-miles per month. The peak came in December, 1955, with 6,918,000 ton-miles. . . .American is having 27 DC-6B's converted to carry 62 passengers instead of 54. . . .Walter W. Candy, Jr., of Los Angeles, and Ralph S. Euler, of Pittsburgh, have been elected to the Board of Directors.

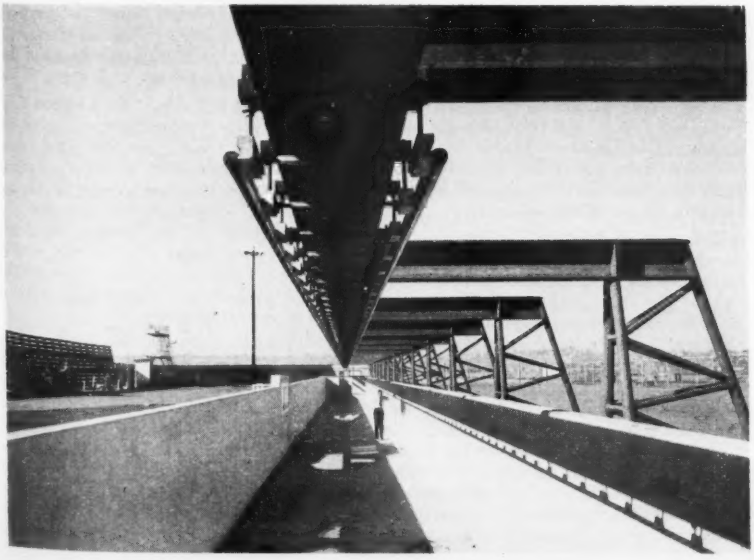
• **Arma Division, American Bosch Arma Corporation . . .** Alan F. Thompson has been named Vice-President for Manufacturing. He was formerly Manager of Manufacturing Control for Convair, A Division of General Dynamics Corporation.

• **Bell Aircraft Corporation . . .** In 10 years since Bell's Model 47 received the world's first commercial helicopter certificate from the CAA permitting it to carry passengers "for hire or reward," the company has manufactured 1,700 helicopters, of which 500 were sold commercially. Bell is manufacturing three of the six helicopters now in production for commercial use. A fourth Bell design, Model 47J, is in the final stages of CAA certification tests. Bell claims it has built more helicopters than any other manufacturer and more commercial helicopters than all the others combined. Altogether, the CAA has certificated 17 helicopter types for commercial use. . . .The Bell Helicopter Division in Fort Worth is turning out H-13H helicopters for the Army.

• **Bendix Aviation Corporation . . .** The Pacific Division, which owns American rights to the Decca Navigation System developed in England during World War II, is assisting the Army Signal Corps in extensive evaluation tests being conducted at the Army Electronic Proving Ground in the Southeastern Arizona desert. The Bendix-Decca system transmits low-frequency radio waves as a continuous chain from a main transmitter and its slave stations, spaced 70 to 100 miles apart. The radio waves form a precise grid pattern ranging from sea level to extreme altitude. Each chain covers an area of about 175,000 sq. miles. There are no blind spots. The system can provide a continuous, all-weather flight-position picture for helicopters and other aircraft, sea-going ships, and mobile ground units.

• **Convair, A Division of General Dynamics Corporation . . .** A 300-ft. towing tank, the first unit in a proposed $750,000 hydrodynamics laboratory, has been completed at the San Diego plant. The towing basin, which has an overhead monorail for towing test models through the water, will be used for hydrodynamic research in the development of jet and turboprop seaplanes and to develop team combinations between water-based aircraft and surface ships. The hydrodynamics laboratory also will engage in underwater ballistics studies and in the investigation of supersonic aircraft shapes, using water as a high-density test fluid instead of air. The concrete basin is 6 ft. deep and 12 ft. wide. It has heavy plate glass windows on the bottom and walls to permit photographing models during the test. Convair plans to make its hydrodynamics laboratory available to the West Coast maritime industry for research on ship hull designs. The laboratory will consist of two 300-ft. towing basins, a 100-sq.ft. turning basin in the middle, and an office structure.

This 300-ft. towing tank will be the first unit in a $750,000 hydrodynamics laboratory to be constructed by Convair, A Division of General Dynamics Corporation, at its main plant in San Diego, Calif. The basin, which will be covered, is 6 ft. deep and 12 ft. wide. The overhead monorail is for towing dynamic scale models of seaplanes through the water. Shipbuilders may be allowed to use the tank, too.

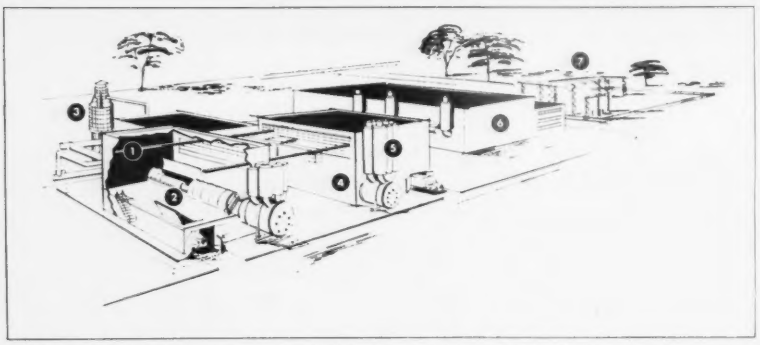


• **Douglas Aircraft Company, Inc. . . .**The DC-8 jet transport now being offered commercial air lines—somewhat larger than the original model—has a wing span of 139 ft. 9 in. and a gross weight of 265,000 lbs. for the domestic version or 287,500 lbs. for the intercontinental, long-range version. There will be a choice of three engines. The fuselage has been lengthened 100 in. to provide space for 19 more passengers in tourist planes. The first-class DC-8 cabin will contain 118 to 122 seats and the all-tourist cabin up to 144 seats. Cruising speed will be 550 to 580 m.p.h. Maximum range of the intercontinental model has been increased to 6,720 miles. Douglas has firm orders for 107 DC-8's from ten air lines, according to a recent announcement.

• **Elastic Stop Nut Corporation of America** announces new self-aligning anchor and gang-channel locknuts for bolting attachments to large forgings in aircraft construction where misalignment of surfaces presents a fastening problem. Based on the ball-joint principle, they can be installed without machining, milling, or other preparation of the forgings presently used to obtain the required parallel surfaces for normal bolting.

• **Fairchild Engine and Airplane Corporation . . .**Fairchild Guided Missiles Division, of Wyandanch, N.Y., has been elected to membership in the Radio Technical Commission for Aeronautics. The Division is engaged in research on and development of pilotless air-borne systems, navigation problems pertaining to such systems, and their adaptation to both military and civil air-borne requirements.

• **The Firestone Tire & Rubber Company . . .**Firestone research scientists have designed and constructed a machine to test the strength and elasticity of rubbers at higher temperatures than have ever before been used in making such measurements. The electrically powered tester is used in the quest for new synthetic rubbers that will be capable of performing satisfactorily at temperatures that burn or melt most rubber products. These new heat-resistant rubbers are needed for use in high-speed aircraft and missiles subject to aerodynamic heating, as well as for high-speed tires and numerous industrial rubber products. Company chem-



This artist's sketch shows the principal features of General Electric Company's proposed $20,000,000 supersonic propulsion test facility. Scheduled for completion in 1958, it will be constructed at the Aircraft Gas Turbine Division plant in Evendale, Ohio. The numbers identify: (1) Test Cell No. 1, (2) Test Chamber, (3) Air Heater, (4) Test Cell No. 2, (5) Exhaust Silencer, (6) Compressor Building, and (7) Electric Substation.

ists are analyzing scientific records of high-temperature performance of known and new synthetics. Present published data on rubbers go no higher than 400°F. Firestone's new machine is capable of use up to 1000°F. It is enclosed in an insulated chamber heated by 14 electric units that use 15,000 watts. The device maintains constant temperature with great accuracy. The chamber has a window made of five layers of plate glass for visual inspection of the tests.

• **General Electric Company.** . .During a confidential tour of its research and development facilities at the Aircraft Gas Turbine Division, near Cincinnati, G-E revealed plans to construct a $20,000,000 test facility capable of simulating supersonic flight conditions for jet engines three times more powerful than any currently in production. Addressing the delegation of aircraft executives and Air Force officers, Jack S. Parker, MIAS, General Manager of the Division, said the new facility, to be completed in 1958, will be financed by G-E and will be constructed near the present jet-engine plant in Evendale. He remarked that the Division's present facilities, including two departments in Lynn, Mass., would cost $100,000,000 to replace today. Claiming the new supersonic test facility will be "the most advanced of its type in this country," he said it will be able to simulate the conditions a large jet engine would encounter flying at 2,300 m.p.h., or three and one-half times the speed of sound, at 60,000 ft. It will also be possible to duplicate conditions experienced during a dive. The main part of the facility will be two altitude test cells, each with a diameter of 18 ft. Vast amounts of air, flowing at supersonic speeds, will be forced through the cells. The air will be cooled or heated, as required, before entering the cells. In some cases, two airflows of different temperatures will be mixed close to the cells to obtain the required test conditions. A crew of about 100 men will operate the facility, which will use more than 80,000 kw. of electric power. The test cells will have mufflers to reduce noise. . . .G-E's Instrument Department is manufacturing a new in-flight refueling transmitter with 50 times the capacity of earlier mass fuel flowmeters. Mounted in the fuel line leading to the boom which extends from the tanker plane during the refueling process, the flowmeter measures up to 600,000 lbs. of fuel per hour.

• **The B. F. Goodrich Company** has resumed the production of flexible rubber fuel cells for military aircraft at its Los Angeles plant.

• **Goodyear Aircraft Corporation** has developed a general-purpose analog computer that can be tailored to highly specialized applications in engineering and business research. Primarily designed for the mathematical analysis of highly complex systems, the new GEDA A-14 also permits the solution of direct simulation problems. A split-problem board makes it possible to work on two separate problems simultaneously. The console houses up to 96 operational amplifiers and 50 or more nonlinear elements, providing one complete computing system or two independent smaller systems. The computer can be expanded to any size. It has a built-in problem analyzer which checks the actual wiring of a problem both during and after setup. An automatic dialing system permits all operations to be monitored.

• **Harvey Aluminum Division of Harvey Machine Co., Inc.** . . .Hollow aluminum bar stock, a new mill product, is in full-scale production. The company claims the hollow metal offers machine-tool operators all of aluminum's favorable machining characteristics at substantial savings over conventional bar stock. The aluminum alloy utilized is 6066, a wrought alloy developed by Harvey Aluminum. It is said to have excellent machinability, superior corrosion resistance, high strength, and excellent finish.

• **Kollsman Instrument Corporation** has developed what it claims to be the first integrated flight instrument system. Designed for high-performance transport planes to meet the demands of commercial air lines, it appears to be a significant step toward solving the problems of altitude separation, cruise control, and navigation dead reckoning. Douglas Aircraft Company, Inc., has accepted the system for use in the DC-8, according to Kollsman. The advantage of the system is that it depends upon conventional pressure instruments which are connected electrically to each other and to a computer but which can function independently. By means of this electrical connection, standard indications are made considerably more accurate, and new information is obtained. In the event of electrical interruption, the pilots continue to receive pressure readings so that indicated and maximum allowable air speed and Mach Number are not affected, while altimeter indication reverts to its normal pressure accuracy. Along with corrected altitude, Mach Number, and indicated and maximum allowable air speed, the system presents to the air-line pilots important information not available before—minimum safe speed for approach and landing, most efficient cruising speed, and true outside air temperature (used in detecting and flying the jet streams). True air speed also is given directly so that involved computations are not required. The nucleus of the system is an altimeter that has a new high accuracy with realistic errors of not over 50 ft. at sea level and 100 ft. at 40,000 ft. Designed for easy readability, the altimeter registers thousands of feet on a counter or drum and shows hundreds of feet with a pointer.

The Kollsman integrated flight instrument system consists of three pressure instruments—a sensitive altimeter, a standard IAS instrument, and a Machmeter. The system also includes an angle-of-attack sensor, an OAT probe, and a computer. By means of servocomponents, the instruments are interconnected to each other and to the computer. Information signaled from one instrument is used to correct the data of other instruments.

While there are only five sensing units, each one carries out more than one function. For example, data for both Mach Number and angle of attack are fed into the altimeter to correct for the inherent error in the aircraft's static-pressure system. To correct for instrument error, information from the altimeter is servoed to the computer, where it is acted upon by a scale-error corrector, and the precise correction is fed back to the altimeter. Moreover, by combining Mach Number with outside air temperature, true outside air temperature and true air speed are obtained. Information from the angle-of-attack sensor is fed to the air-speed indicator, where the minimum safe speed and most efficient speed are presented.

• **The Liquidometer Corporation** announces a new liquid-quantity gage for measuring liquid oxygen and other liquid gases. Highly resistant to shock and vibration, it employs a capacitor-type sensing unit in the liquid-oxygen container. A self-balancing bridge network measures and indicates quantity. The only moving parts are those in the motor-driven indicator. The liquid-oxygen gage operates on 115 volts, 400 cycles.

• **Lockheed Aircraft Corporation** announced recently it was conducting hydrostatic (underwater) tests on the C-130 Hercules prop-jet transport at its plant in Marietta, Ga. The tests were similar to those performed on the British Comet. A concrete pool was built for static testing the aft and nose sections of the fuselage, which were bulkheaded, made watertight, and then submerged in the water. Water from

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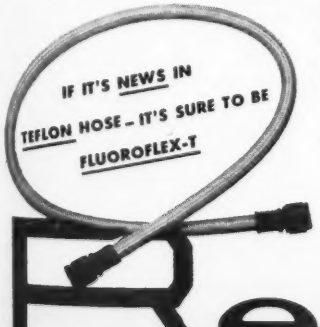

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A new version of the Martin Matador, the TM-61B, has been test-fired successfully at Holloman AFB, according to an announcement by The Glenn L. Martin Company. The new missile is longer and has a larger nose section than its predecessor. For tactical missions with the Air Force, the TM-61B will be given an entirely new air-borne guidance system. The Matador, which is about the size and weight of a jet fighter, is launched from a mobile semi-trailer and flies at more than 650 m.p.h.

a fire hydrant was then introduced into the fuselage section until a pressure differential of 15 lbs. per sq.in. was attained or failure occurred. The tests proved these sections would withstand 15 lbs. pressure, which is twice that which the pressurized cabin is subjected to in flight. Since water is incompressible, the tests were run off quickly and without danger. Points of weakness or failure could be detected readily; there was no danger of an explosion damaging the structure or personnel, as in tests conducted with compressed air. In a different series of tests for pressure fatigue, the pressurization and depressurization of the fuselage in 25,000 flights was simulated by water pressure. It was thought 25,000 cycles of repeated-loads tests would prove the lifetime structural integrity of the Hercules. . . .The first production model of the C-130 has been undergoing a series of operational tests at temperatures ranging from −65° to 165°F. in the climatic hangar at Eglin AFB, Fla. The Air Proving Ground Command tested the hydraulic systems and all other operational features at extreme temperatures.

• **Manning, Maxwell & Moore, Inc.** . . .The Aircraft Products Division announces a new differential pressure transducer with a wide range of measurement applications in the aircraft industry. Input signals can be differential pressure, differential suction, and straight pressure or suction. Applications in test work include gage calibration and recording of any of the input signals.

• **Marquardt Aircraft Company.** . .Under Air Force sponsorship, the Marquardt Jet Laboratory will be modernized at a cost of $4,500,000. The improvement is part of a $6,000,000 expansion program announced by the company which will add 40 per cent more floor space to the plant at Van Nuys, Calif. Plans call for a test engineering building, a warehouse, and an addition to the power-plant engineering building, in addition to leased office space. The Jet Laboratory will gain four new compressors, 16 air storage tanks, four exhausters, a second high-altitude test cell, and facilities for extreme-temperature environmental testing. The resultant increases in air capacity will meet the need for "free jet" testing of supersonic ram-jet engines under simulated altitude conditions and for high airflow test runs of longer duration, with shorter intervals between tests. Free jet testing provides external, as well as internal, airflow at the ram-jet engine inlet and more accurately simulates supersonic flight performance through direction of the air blast to provide either angle-of-attack (climbing or diving) or yaw (turning) conditions. . . .The company has announced the establishment of an Individual Professional Development Program for its technical staff in view of an anticipated 100 per cent increase in personnel this year. The program will be administered by the Professional Personnel Section with the guidance of an advisory committee composed of company engineers. More engineering and technical courses, and possibly scholarships and fellowships, will be established for Marquardt engineers.

• **McDonnell Aircraft Corporation.** . .The F3H-2N Demon, carrier-based jet fighter, has completed its flight introduction program at the Naval Air Test Center and joined the United States Fleet. The first six planes were delivered to Fighter Squadron 14 in Jacksonville, Fla., on March 7. McDonnell claims that the F3H-2N, powered by the Allison J-71 engine, is the fastest all-weather Navy fighter now in service. . . .Announcing the highest backlog in its history—$622 million—McDonnell Aircraft Corporation said in March that its payroll of 15,150 was slightly larger than its peak payroll during the Korean war.

• **Meletron Corporation.** . .The Model 1400 pressure switch, designed for jet-engine use and other applications where vibration and temperature problems require improved performance, is now in production. The result of 8 years' research and development, it is expected to fill a need of aircraft manufacturers confronted with the problem of instrumentation under high-temperature conditions. This pressure switch can be used for fuel, oil, pneumatic, or hydraulic applications. It employs either an aluminum or stainless steel actuator (sensing element) with present range to 400°F. and projected design up to 600°. No seals, springs, or linkages are employed. One moving part works directly on a snap-action switching element.

• **Northrop Aircraft, Inc.** . . .The F-89H Scorpion, first operational airplane to be equipped with the Hughes Falcon air-to-air guided missile, is now being delivered to the Air Defense Command. The twin-jet, all-weather interceptor, carrying a pilot and radar operator, is armed with both Falcon missiles and folding-fin rockets. The effective range of the 100-lb. guided missiles is greater than that of rockets or air-borne cannon. It is not necessary to aim the missile precisely at the target since it can track the enemy down at supersonic speed. The F-89H, the company claims, is America's most heavily armed interceptor.

• **Nuclear Development Corporation of America** is constructing a "hot" radiochemical laboratory at its Nuclear Experimental Station in Pawling, N.Y. The new laboratory will be used primarily to study the effects of radiation on fuel elements and structural components of nuclear reactors by examining the radioactive test specimens after they have been irradiated in a test reactor such as the one at Arco, Idaho. A secondary use will be to study the effects of radiation on non-reactor materials. The new laboratory will enable N.D.A. to investigate possible uses for nuclear radiation in such fields as food sterilization, polymerization, and production-control devices.

• **Pan American World Airways, Inc.** . . .Under a contract of approximately $2,000,000 with the International Cooperation Administration, P.A.A. will send 25 technicians to Thailand for 3 years to assist the government-owned Thai Airways Company Ltd. in training employees and expanding its operations. The training program will include air-line management; repair, maintenance, overhaul, and operation of aircraft, engines, and equipment; use of communication facilities; traffic and sales, processing of traffic, and accounting procedures. . . .Pan American is undertaking similar development projects under ICA financing in Turkey and Pakistan.

• **Piasecki Helicopter Corporation,** of Morton, Pa., has changed its name to

Vertol Aircraft Corporation. The company is currently manufacturing H-21B and H-21C helicopters for the Army, Air Force, and Royal Canadian Air Force. The firm's wholly owned subsidiary in Arnprior, Ont., has been renamed Vertol Aircraft Company (Canada) Ltd.

• **J. B. Rea Company, Inc.,** of Santa Monica, Calif., has issued a booklet describing its services and equipment for simulation, computing, data reduction, and data processing. . . .The company announces a new line of miniature hysteresis synchronous motors, developed for applications in which the maximum horsepower per unit weight and volume is the primary consideration. The motors can be supplied with speeds of either 8,000, 12,000, or 24,000 r.p.m. . . .A low-frequency noise generator has been designed for use with d.c. analog computers. Various statistical quantities such as air turbulence, radar noise, vibration, and other noise interferences can be simulated by the injection of filtered random signals.

• **Solar Aircraft Company. . .**Under sponsorship of the Navy Bureau of Ships, a 500-hp. Jupiter gas-turbine engine has been installed in a 40-ft. Navy personnel boat to create a speedy, propeller-driven experimental craft. The variable-speed Model T-522J engine weighs 1,000 lbs., one fourth as much as a comparable marine diesel engine. Its power output can be varied without affecting the compressor speed. The engine is 6 ft. long. It has a ten-stage axial-flow compressor and a three-stage axial-flow turbine. The rotor turns at 20,000 r.p.m.

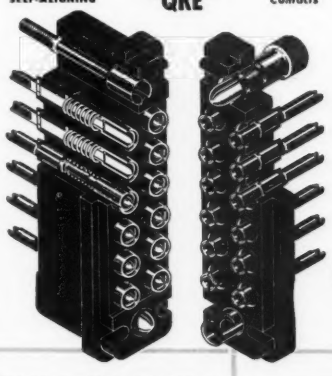
• **United Air Lines, Inc. . . .**The Port of New York Authority is constructing a $3,000,000 hangar at Newark Airport for occupancy by United Air Lines. The first hangar built at Newark since World War II, the new structure will measure 300 by 200 ft. and will be completed in October, 1957. . . .United has placed five new DC-6A's in all-cargo service. They cut 5 to 6 hours off transcontinental schedules. . . .Bassinets have been installed in United's DC-7 Mainliners for the convenience of traveling mothers.

• **Vickers Incorporated. . .**A new Administrative and Engineering Center has been completed in suburban Detroit. Research and engineering laboratory facilities and other technical activities occupy the major portion of the 150,000 sq.ft. of floor space. More than 700 persons are employed there. . . .Vickers announces a new line of constant-speed motors with integral anti-overrun flow control for use in aircraft oil-hydraulic systems.

• **Westinghouse Electric Corporation. . .** Scales and balances for the Propulsion Wind Tunnel and the Gas Dynamics Facility at ARDC's Arnold Engineering Development Center, Tullahoma, Tenn., will be constructed at the Westinghouse plant in Sunnyvale, Calif. . . .The Aero 13 fire control system for the Douglas F4D Skyray will be manufactured by the Westinghouse Air Arm Division. It is designed to enable the carrier-based jet fighter to detect and destroy enemy aircraft at night or under no-visibility weather conditions.

WINCHESTER ELECTRONICS, INC.

QUICK-DISCONNECTING SELF-ALIGNING **SERIES "QRE"** 6, 12, 18, 24, 34, 208 Contacts



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SUB-MINIATURE **SERIES "SMRE"**

7, 14, 20, 26, 29, 34 Contacts

ACTUAL SIZE

HEAVY DUTY **TYPES "200" to "900"**

Used in "AN" Shells

¼ ACTUAL SIZE

SERIES "M" MINIATURE

4, 5, 7, 9 Contacts

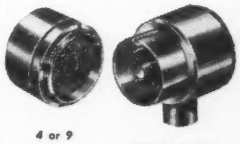
ACTUAL SIZE

SERIES "HM" HERMETIC PLUG (Round Hole)

Used with "M" Receptacles

ACTUAL SIZE

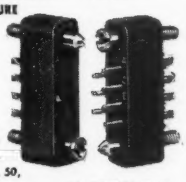
TYPES "RA" & "RB" WATERPROOF



4 or 9 Contacts

⅓ ACTUAL SIZE

SERIES "MRE" MINIATURE



7, 8, 9, 14, 18, 20, 21, 26, 34, 41, 50, 75 Contacts

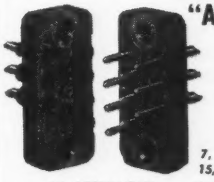
⅓ ACTUAL SIZE

SERIES "HMRE" HERMETIC PLUG

Used with "MRE" Receptacles

ACTUAL SIZE

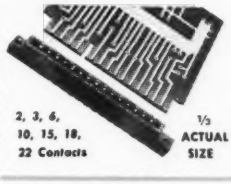
AIRCRAFT **SERIES "A"**



7, 10, 15, 18 Contacts

½ ACTUAL SIZE

SERIES "K" RECEPTACLES Used with Printed Circuit Cards



2, 3, 6, 10, 15, 18, 22 Contacts

⅓ ACTUAL SIZE

TYPE "B" MOISTURE PROOF

12, 14, 24 Contacts

½ ACTUAL SIZE

Many features are covered by our Patents: Nos. 161900, 162792, 2411861, 2466370, 2513080, 2526325, 2532538, 2633482 and 2659872.

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IAS SECTIONS

Meet Your Section Chairman

Hermon H. Cole, Jr.

St. Louis Section

Hermon Harrison Cole, Jr., of McDonnell Aircraft Corporation, is Chairman of the St. Louis Section for 1955–1956. He is Project Engineer for the twin-jet, super-sonic F-101A Voodoo.

Hermon was born in Springfield, Ill., in July, 1918. He was graduated from Springfield High School in 1936 and attended the University of Michigan from 1936 to 1939 as a premedical student. Hermon's love for airplanes apparently got the better of him in 1939, and he switched to the Spartan School of Aeronautics. He was graduated from Spartan in 1942 with an A.A.S. degree. During this same period he also became a private pilot.

Hermon joined the McDonnell Aircraft Corporation in May, 1942, and began his career in the design department. In 1944 he entered the Navy and was a radar technician until his release in 1945.

Hermon resumed his career in design upon his return to M.A.C. in 1945 He worked on most of the M.A.C. airplanes such as the XP-67, XF-88, F2H, F3H, and F-101. Hermon advanced from Designer to Group Engineer in 1947 and to Assistant Project Engineer in 1951. He assumed his present position as Project Engineer in May of 1955.

Hermon has been active in local IAS work for some time and is currently doing an excellent job as Chairman of the St. Louis Section. He is married, has two children, and resides at 8244 Cadillac Lane, Berkeley, Mo.

Traffic Control

Boston Section

A meeting was held on the evening of February 15 in the new Waltham plant of Sylvania Electric Products, Inc., with 60 members and friends present. Ben F. Greene, Chief of the Navigation Laboratory, USAF Cambridge Research Center, spoke on "Air Traffic Control." His presentation was followed by a lively question period.

Mr. Greene presented the stern realities relative to the present air traffic control situation. Looking into the future, he said that by 1960, when jet transports are placed in service, it appears that we are headed for catastrophe. The present en route system was developed for 300 m.p.h. aircraft having 2,000 ft. per min. rate of descent and 22,000 ft. maximum operating altitude. Jet transports and military jets of Mach 2 or 3 capability introduce rates of descent ten times as great and much higher altitudes. Also, the present system was designed for bad-weather use only. With the advent of high speeds, all-weather control is needed because the very short closing times for approaching aircraft do not allow a pilot sufficient time to take corrective action.

The apparently unlimited airspace is severely limited by the economic need for airplanes to depart and arrive at certain times of day and to use the same routes and altitudes. Mr. Greene said that uncertainty in establishment of aircraft position, in the case of an Air Force fighter, requires reservation of a block of airspace 2,000 ft. high by 150 miles wide by 15 min. of flight distance long. As for the present control system, he characterized this as a paper-and-pencil system which is made safe by limiting severely the rate of traffic flow under IFR conditions.

This situation is not due to lack of planning, for in 1945 a plan for radar control of airways was recommended on which no action was taken. Again in 1953 a recommendation similar in substance was made. At the present time, 45 radars are in use under CAA and 78 under USAF. Of this Air Force number, perhaps half are not in this country. No possibilities for improvement may be seen in the near future.

In the vicinity of airports, approach radars are adequate at present traffic rates in good weather, but these rates slow to 50 per cent under IFR conditions. Present stacking procedures will not be possible for jets because of their relatively poor ability to loiter. Another limitation on traffic rates during the approach is the lack of correlation in the ground control stations between radar data and the cards on which the progress of the flight of each aircraft is noted. Mr. Greene mentioned the so-called Rapcon system in which this difficulty is to some degree ameliorated although only three of these systems are currently in service. As for ground surveillance, a single ground radar designated as ASDE is in existence. Without such equipment, all-weather operation for high traffic rates will be limited on the ground by inability to keep track of aircraft on runways and taxiways.

With regard to research and development in air traffic control, the efforts to date have been inadequate to enable progress at the needed pace. CAA has but a small group at work on this critical problem. The Navy and the Air Force have carried on programs to meet their own needs.

Mr. Greene described the Tracal and Volscan systems. Tracal has the function of smoothing the flow toward an airport between radii of 60 and 120 miles. It is based on a tracking radar and associated computer which continuously computes estimated time of arrival for each approaching aircraft using its present distance and azimuth and their rates of change for the computation. If this shows aircraft arriving too close in time to each other, they may be separated by instructions to change speed and course suitably. The Volscan system operates within a circle of 60 miles radius in a manner generally similar to that just described.

On the basis of the estimated arrival time for an aircraft, a particular landing time is assigned and reserved for that craft. The spacing between successive arrivals is 15 sec. If progress of a particular flight is too rapid, arrival is delayed by instructions to fly a longer curved path. This system is capable of correcting for winds aloft and in tests; over 98 per cent of 3,000 arrivals, of which 1,000 were jets, have been brought in within 9 sec. of the correct time. Mr. Greene called attention to the need for improved height-finding equipment—an important lack in this system.

Mr. Greene stated that future systems must include couplers with automatic pilots in order to eliminate slow pilot reactions. He also indicated that domestic air traffic control cannot wait for the development of a so-called ultimate system. He marked the operational use of jet transports as the time when the present system will be totally unacceptable.

WALTER MCKAY, *Secretary*

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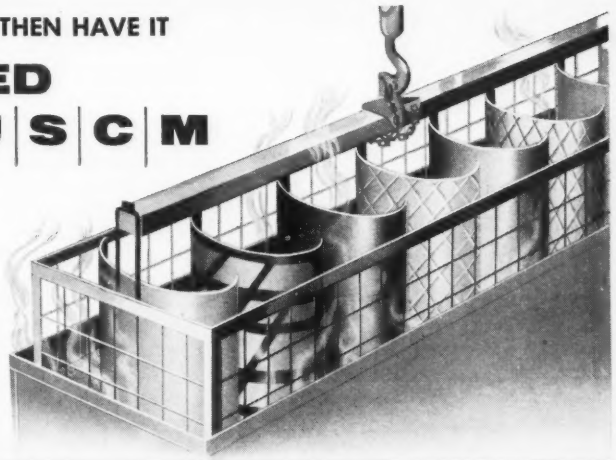

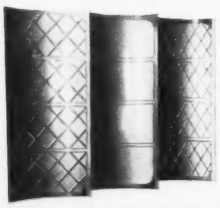

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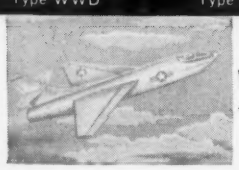

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Jet Transports

Chicago Section

The January 11 meeting was opened by Richard A. Schram, Chairman of the Advisory Board, in the absence of the Section Chairman, J. W. Pocock.

Mr. Schram introduced James Obertino, Chief Flight Engineer, Trans World Airlines, Inc., who introduced the speaker, R. W. Rummel, Chief Engineer, TWA.

Mr. Rummel described the basis for the selection of an aircraft for air-line use, the specialized detail design requirements for a given air line, and a prognostication of future aircraft.

TWA gave consideration to jet-type aircraft as early as 1944 and followed through as far as performance analysis at that time. Early attention was given to British jet transports because of their advanced development. (The Comet project was started in 1943.)

Present pure jet transports designed by American companies, however, have no competition from other countries. The Boeing 707 evolved from experience gained with the B-47 and B-52. This project was the result of 30 airfoil sections and 155 wing models investigated; 24 flutter models tested, etc.; and 27,000 wind-tunnel hours.

Mr. Rummel outlined the procedure followed in the selection of a transport aircraft. This entailed consideration of the foremost advantages of the aircraft, including assurance of competitive lead by use of the aircraft; the weight; and the power-plant growth. The detail design must be accomplished by the aircraft manufacturers in cooperation with the air line to meet the latter's specific requirements. Other considerations include analysis of systems segregation, structural conservatism, and crashworthiness. Once production of an aircraft is contracted, an air-line engineering office is established at the plant to follow through the final detail designs.

In prognostication, Mr. Rummel predicted the use by air lines of a large-type helicopter or convertiplane by 1960. The Boeing and Viscount airplanes will be used extensively. Supersonic transports are a long way off, and atomic-powered aircraft will not be used commercially in the foreseeable future.

HARRY WIANT, *Secretary*

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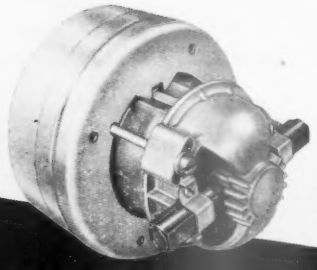

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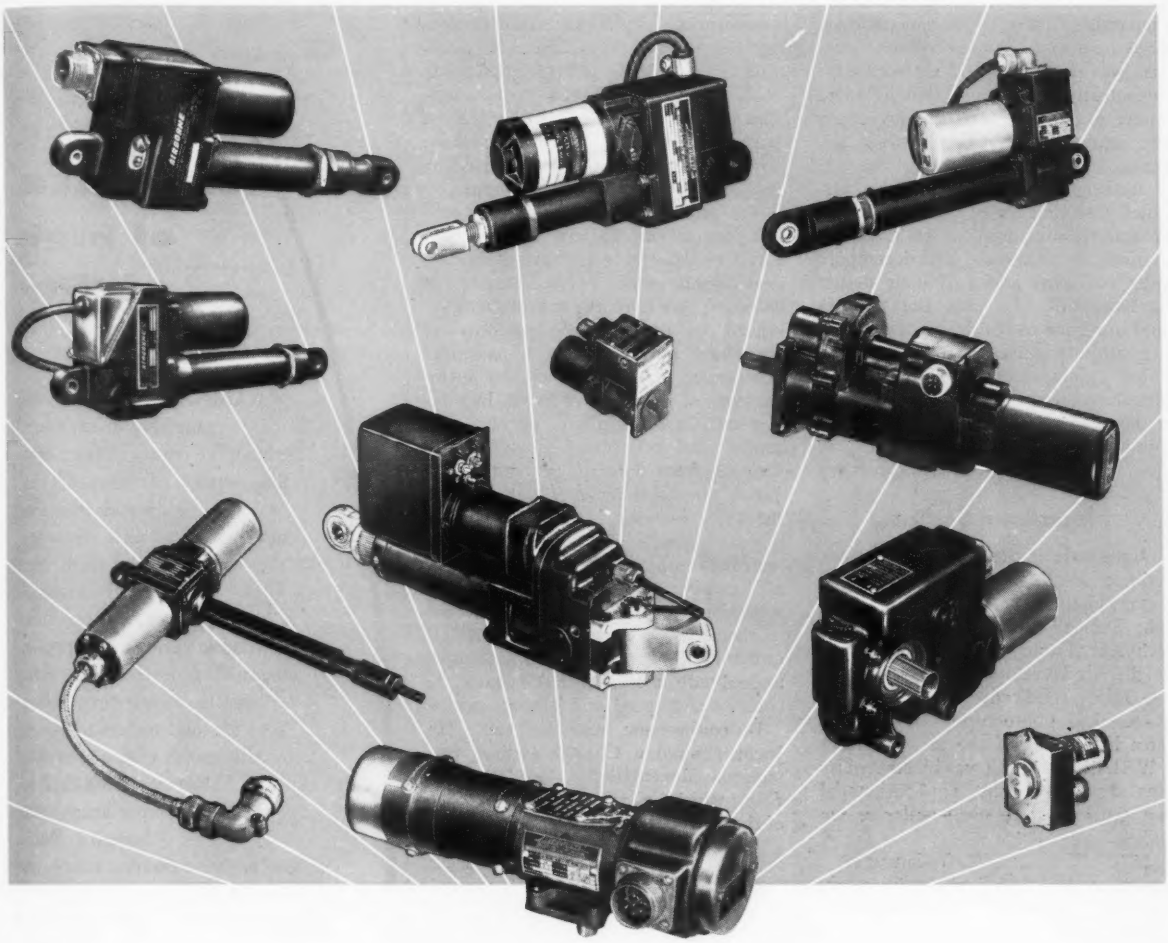
Dayton Section

One hundred members and guests of the Dayton Section met for dinner at Cordell's Supper Club on February 21. The evening's program offered a discussion of "Nuclear Propulsion in Transportation" by two scientists of the General Electric Company, N. J. Bifano and J. Moteff.

Mr. Bifano, who is Supervisor of Analysis and Shield Design in the company's Aircraft Nuclear Propulsion Department, said the application of nuclear propulsion to aircraft would be ideal because of the adaptability of aircraft to a highly concentrated source of heat. He pointed out that range in the case of nuclear-propelled aircraft would be limited only by human endurance. He mentioned the types of aircraft nuclear propulsion: turboprop with steam or air as the working fluid, the ducted fan, the turbojet, and the ramjet with a reactor substituted for the normal chemical fuel combustion cans.

Mr. Moteff described the role of the moderator and the control rods. He pointed out that humans would have to stay more than 1 mile away if the radiation were unchecked and that a shield was therefore necessary. It would be composed of light elements for neutron-radiation shielding and heavy elements for gamma-radiation shielding. The shield, of course, must be so designed as to permit passage of coolants.

Early estimates indicated the shields would weigh from 50 to 100 tons, which is roughly comparable to the fuel weight of the largest modern chemically fueled bombers; hence, it was considered likely that the nuclear aircraft would be



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comparable in size to the newest long-range bombers. One difference, however, was that the shield represented a concentration of weight which would require a considerably different structure because of the wing bending moments.

Another problem discussed by Mr. Moteff was that many materials which are traditionally used for electrical insulation, lubrication, etc., decompose under radiation and lose their design characteristics. To ease the public's mind in regard to the danger associated with aircraft nuclear propulsion, Mr. Moteff reminded the audience that, since the crew must be protected, surely anyone farther away would be safe from the nuclear radiation.

T. J. KEATING, *Secretary*

Hagerstown Section

Wives were invited to the February 14 dinner meeting, held in the American Legion Home. The speaker was Lt. Col. Samuel A. Custer, Head of the Technical Photo Service Branch at Wright Air Development Center, Dayton, Ohio. He discussed the utilization of technical photography by the Air Force in support of the test programs at WADC. The talk was illustrated by films showing current applications of photography in technical and research studies.

C. L. CHUMLEY
Secretary-Treasurer

The Viscount

Hampton Roads Section

Hugh F. Jacox, Assistant Sales Promotion Manager of Capital Airlines, Inc., spoke to 85 members and guests of the Hampton Roads Section on February 21 at the NACA Langley Laboratory. Chairman Albert L. Braslow introduced the speaker.

Mr. Jacox spoke with enthusiasm of the Vickers Viscount airplane with which Capital is now replacing its entire present fleet of transports and of the considerations that led to the decision to purchase this airplane. When any air carrier decides upon new equipment, the temptation exists to delay any such purchase in order to await newer developments; on the other hand, however, an air line cannot delay too long in the purchase of new equipment because of the danger of falling behind its competitors in the type of service offered to the public.

Capital has the unique problem of competing with three long-haul carriers on one of its routes while at the same time maintaining efficient service on several short-haul routes. Capital felt that the solution to this problem lay in an airplane in which were combined the most favorable characteristics of its competitors' airplanes. After surveying the airplanes that would be available, both domestic and foreign, Capital made its decision, about 2 years ago, that the Vickers Viscount suited its purposes admirably and contracted for 60 of these airplanes to be powered by Rolls-Royce Dart turboprop engines.

To date, Capital has received and put into service 15 Viscounts and by early 1957 expects to have its entire fleet of 60 in service. The Viscount has exceeded preliminary expectations in regard to performance, economy of operation, and particularly passenger acceptance. For example, the introduction of Viscount service has increased Capital's share of the passenger load between Washington and Chicago from 9 to 51 per cent. Mr. Jacox does not believe that this remarkable increase is due only to the novelty aspect, because the airplane load factors have continued to average a thumping 93 per cent. Noise and vibration levels in the Viscount are markedly lower than in other transport airplanes now in service, and passengers undoubtedly are enthusiastic about the comfort and speed of Viscount service.

In conjunction with his talk, Mr. Jacox showed a Capital Airlines promotional film entitled *A New Concept in Flight* which described the manufacture of the Viscount and its Dart engines.

LEWIS R. FISHER
Recording Secretary

Indianapolis Section

More than 140 members and guests attended the dinner meeting on February 13 to hear a talk on "Reverse Thrust" by Paul P. Datner, of Aerojet-General Corporation.

During the business meeting, Chairman Philip N. Bright reported on the IAS Annual Meeting in New York. John A. Duff, Chairman of the Membership Committee, reported that the Section had 78 members. Ronald M. Hazen and Harold DeGroff were appointed to the Nominating Committee.

Paul Stanley of the Purdue University faculty reported on arrangements for the first IAS Student Paper Competition at Purdue, scheduled for March 12 under sponsorship of the Indianapolis Section.

Mr. Datner opened his talk with the remark that his receipt of American citizenship a few years ago had unfortunately not yet benefited his accent. He then described several types of thrust reversers and summarized their history.

The SNECMA principle licensed by Aerojet in this country was discussed in detail. Mr. Datner stressed the importance of relative simplicity and "fail-safe" features of this design. The basic idea of the SNECMA principle is that

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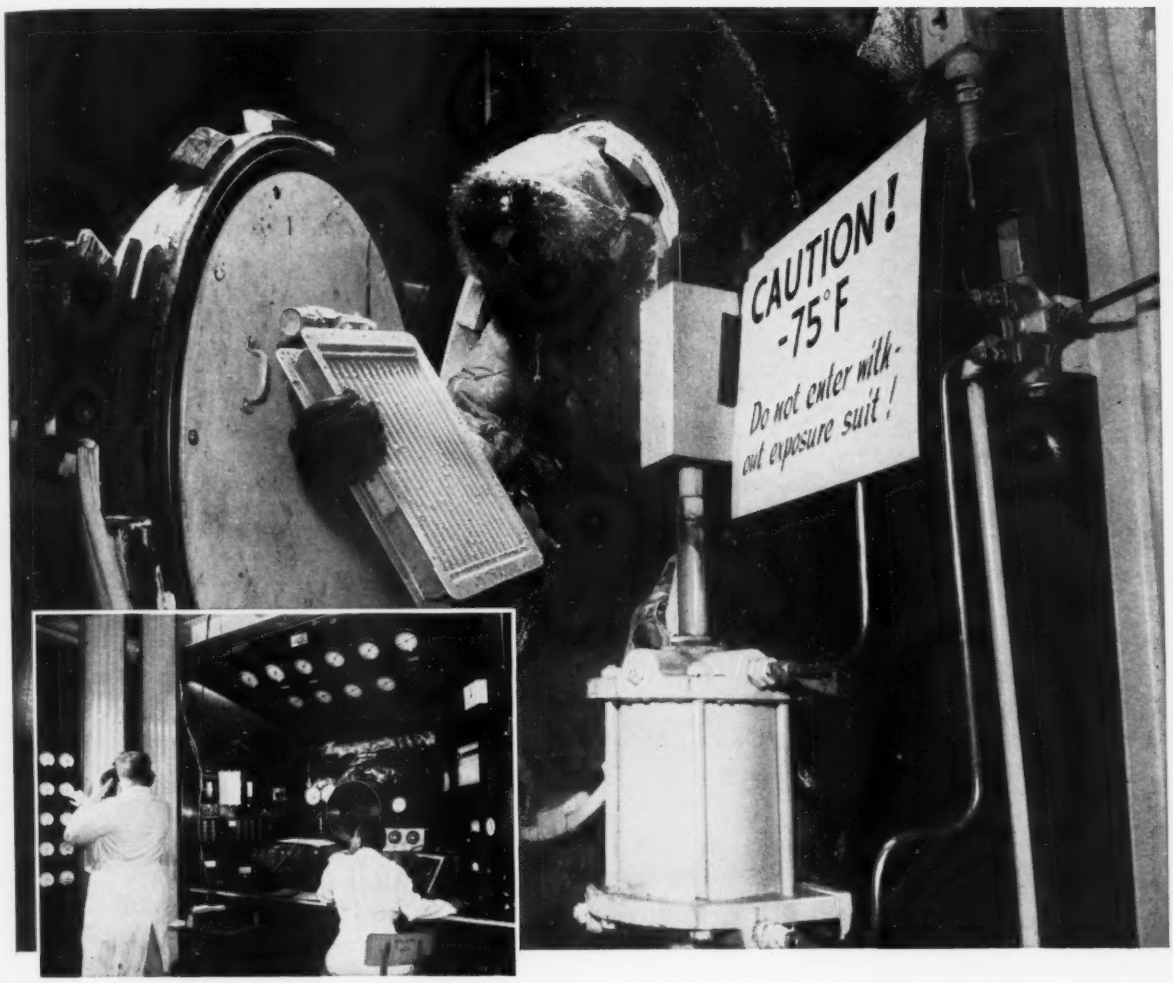

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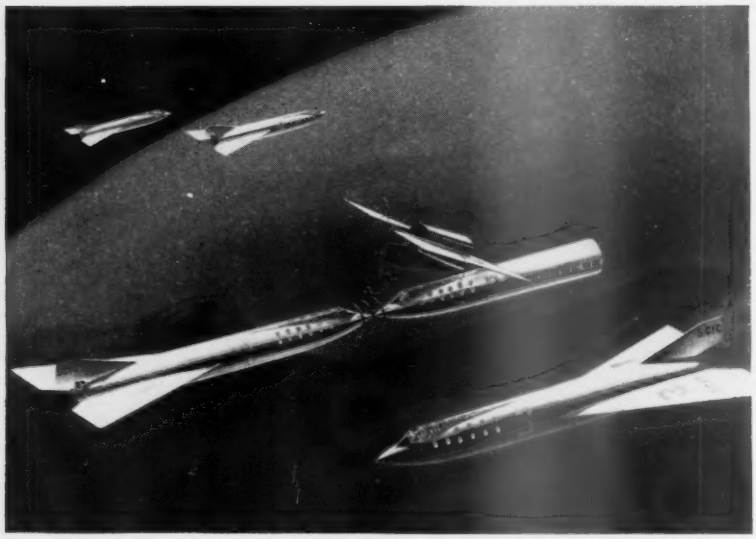

birth of a satellite

Most new ideas, like this inhabited satellite, start out as drawings on a sheet of paper. Here artist Russell Lehmann shows the first step in building the space station proposed by Darrell C. Romick, acrophysics engineer at Goodyear Aircraft.

Two ferry ships, one stripped of rocket units, are joined end to end. As others are added, this long tube forms temporary living quarters for crews. Eventually, outer shell will be built around core, making completed station 3,000 feet long, 1,500 feet in diameter.

No one can be sure which of today's bright ideas will become reality tomorrow. But it is certain that in the future, as today, it will be important to use the best of tools when pencil and paper translate a dream into a project. And then, as now, there will be no finer tool than Mars — from sketch to working drawing.

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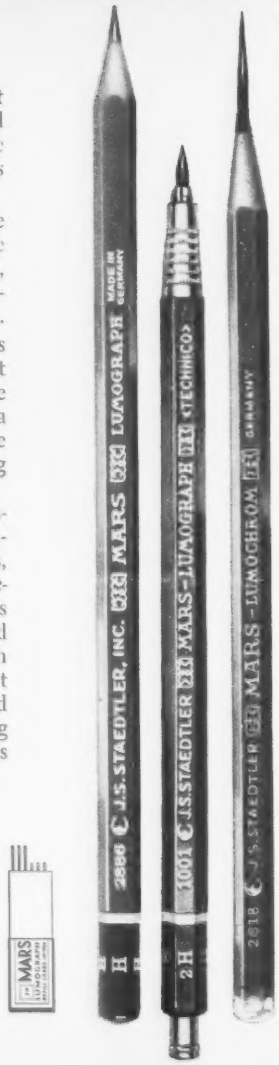

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EPHRAIM M. HOWARD
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Aerial Refueling

Los Angeles Section

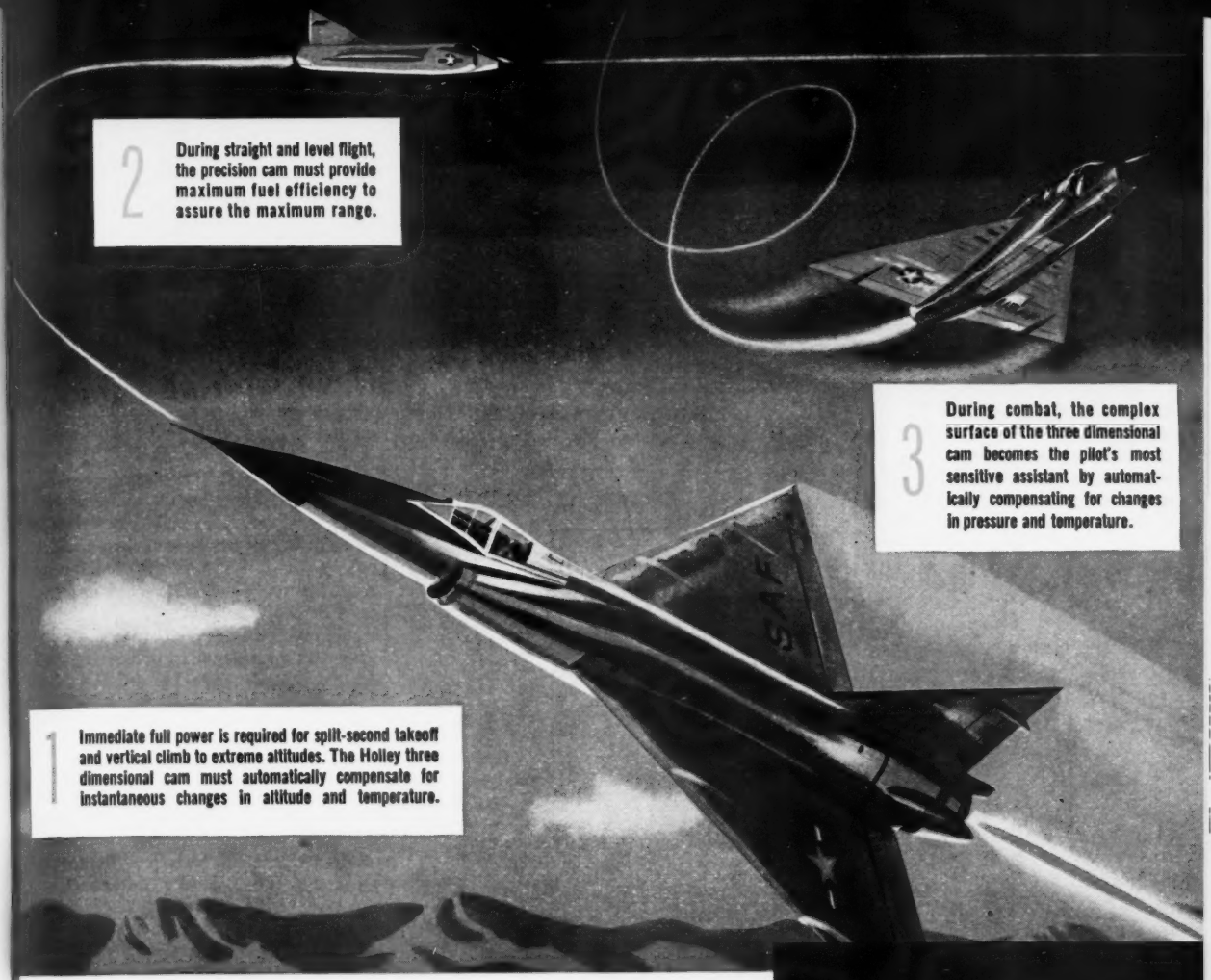
The January dinner meeting featured talks by Gen. Ira Eaker and Col. Pat Fleming on the subject "In-Flight Refueling—Then and Now." General Eaker was the pilot of the Question Mark, which established the first successful in-flight refueling operation during the month of January, 1929. His story of that flight provided many interesting anecdotes of that historic occasion.

General Eaker recalled that the flight was nearly canceled because of the fuel shortage existing in the Army Air Corps at that time. The crew of the Question Mark estimated they would need about 10,000 gal. of gas, and the Air Force "just didn't have that much." Dudley Steele, at that time aviation representative for the Richfield Oil Company, supplied the gasoline to the Air Corps in return for the advertising value of the flight.

General Eaker and others at that time were worried about the limited range capabilities of the Air Corps flying equipment and decided that, if in-flight refueling could be worked out and proved practical, extensive range improvements could be achieved with their present aircraft. After consulting with various Air Corps officials, they obtained permission to modify one Fokker trimotored airplane and two Douglas biplanes for the project.

Soon, preliminary experimentation with various hoses indicated that fuel could be transferred by the airplanes, and ten to fifteen thousand hours of work were put into the aircraft available in preparation for the flight. It was decided to transfer gasoline through a hose dropped out of the refueling plane and held in the tank filler of the receiving plane by one of the crew members. Oil was transferred to the receiving plane in 5-gal. cans because it could not be made to flow through the hose successfully. After consultation with the Weather Bureau, Southern California was chosen as the locale for the flight because flight conditions were best in that area.

The airplanes were ferried from the East Coast to the Southern California area and were made ready for the take-off at 7:24 a.m., January 1, 1929. The Question Mark was air borne with 100 gal. of fuel aboard and immediately refueled after take-off. The first few days of the mission were relatively uneventful


2 During straight and level flight, the precision cam must provide maximum fuel efficiency to assure the maximum range.
3 During combat, the complex surface of the three dimensional cam becomes the pilot's most sensitive assistant by automatically compensating for changes in pressure and temperature.
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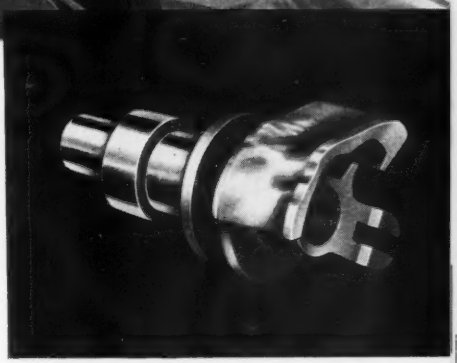

Typical "brain center" of a Holley aircraft engine control. Note the delicate machined surfaces. Each plays a vital role in mechanically regulating the engine under varying conditions.

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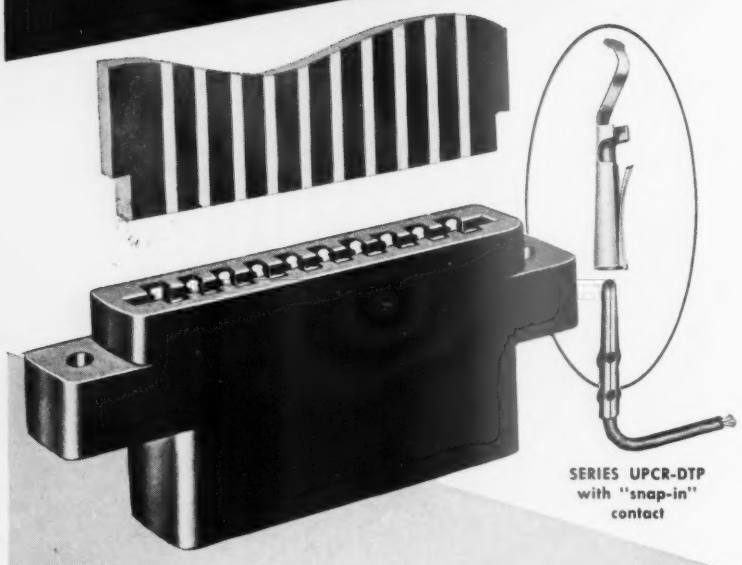

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ful. Refueling contacts were made on schedule during the day and night.

However, on the fourth night the planes were fogged in at two of their bases. Through fortunate circumstances, the refueling operation was completed from the third base with only 5 or 6 gal. remaining aboard. As the flight progressed, engine operation on the Question Mark became marginal, and lesser quantities of fuel could be taken aboard at each refueling until, in the final hours, 50 gal. of fuel were being transferred each hour. The flight ended at 7:01 p.m., January 7, 150 hours and 14 min. after take-off.

The report describing the flight noted among other things that "refueling was both safe and practical. More than 50 refueling contacts were made without mishap, one half of which were made at night. Both range and endurance could be increased by refueling techniques." The final report closed with the recommendation that a project be set up to provide refueling for bombers, pursuit, and observation aircraft.

Colonel Pat Fleming, Deputy Commander of a B-52 Bomber Wing and soon to be Director of Requirements for the Strategic Air Command, reported the growth of in-flight refueling from the Question Mark's start to the point where the Strategic Air Command is now performing one refueling operation every 3 min., 24 hours a day throughout the year. SAC's primary equipment includes a KC-97 tanker and B-47 and B-52 bombers. Some practice refueling operations have been made using the new KC-135 jet tanker. Colonel Fleming reported that refueling operations by SAC have become a routine operational procedure—a fitting climax to the recommendation made in the Question Mark report 27 years ago.

R. G. FULLER, *Secretary*

▶ On January 24, O. E. Balje, Staff Engineer at Hydro-Aire, Inc., described the drag turbine to a Specialist Meeting of the Los Angeles Section.

The drag turbine is a new development using the main engine bleed air. It is ideally suited to accessory drives requiring approximately 5 hp. High efficiency can be obtained without intermediate gearing. Slides were used to show performance characteristics, and the detailed construction was explained by use of a small, but full-sized, cutaway drag turbine.

FRANZ STEINBACHER
Specialist Meeting Coordinator

Mountain Wave

Rocky Mountain Section

This Section's third meeting was held in Denver at the Officers Club, Lowry

AFB, on March 2. After dinner, Lt. Gen. Hubert R. Harmon, Chief of the Air Force Academy, welcomed the more than 100 people attending the meeting and predicted steady growth for the aeronautical industry in the Denver area. He then introduced Joachim P. Kuettner, an international authority on the "jet stream" and "mountain wave."

Dr. Kuettner is now attached to the Cambridge Air Force Research Center in Cambridge, Mass. He has been flying powered airplanes and sailplanes since 1932 and recently, by means of specially instrumented sailplanes, has pioneered in the study of the upper atmospheric conditions in the jet stream and in the areas where the mountain wave is present. He holds the present altitude record of over 43,000 ft. for single-seat sailplanes.

Dr. Kuettner described the jet stream as a belt-like river running entirely around the world from west to east. It is usually characterized by three separate parts, each differing in wind velocity and temperature. The jet streams are quite variable in position, both in altitude and latitude, but are generally in the 20,000 to 40,000 ft. altitude range and have average speeds of 150 knots. Dr. Kuettner defined the jet stream as a local intensification of the general westerly drift which is strong enough to affect flight operations.

The fine structure of the jet stream is being studied under an Air Force contract for which instrumented B-29 and B-47 airplanes are used. The source of the jet stream has not been established, but one theory is that it may be due to convection effects in the horizontal plane. This phenomenon has been reproduced in the laboratory on a model of the earth which permitted the addition of heat at the equator and the withdrawal of heat in the northern hemisphere.

The average position of the jet stream in winter is roughly between California and Florida, with the core at about 30,000 to 40,000 ft. Slides were shown to illustrate the general structure of the jet stream as observed in a flight from Florida northwest, northeast, then northwest again, made by a B-29. Measurements were taken of the vertical speed, pressure, and temperature distributions with time during the flight. It appears from these measurements that the best way to locate a jet stream is through observation of the temperature gradient with altitude and forward distance. The jet stream boundaries are generally quite marked in terms of a sharp change in the normal temperature gradient. Dr. Kuettner pointed out that several air lines are now making use of the jet stream to

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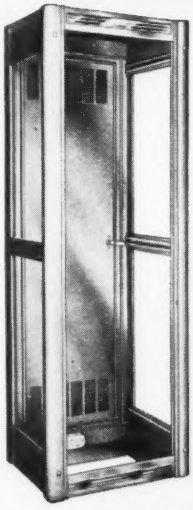
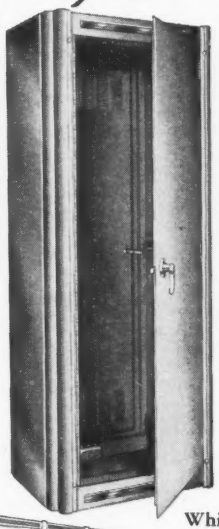
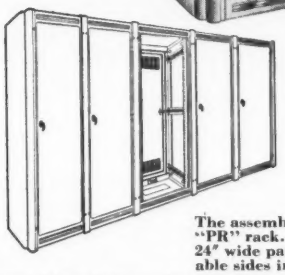




The above unit is our Type "PR" (with rear door only) "Universal Cabinet Rack." Type "FR" (shown with detachable side panels *affixed*) has both front and rear doors.



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Heights: 48⅛", 67⅜", 76⅛" and 83⅛".
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While incorporating new features of versatile assembly, there has been no sacrifice of *structural rigidity.* ALL PAR-METAL RACKS *are substantially welded* and *reinforced* for diversified industrial use.

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The assembly of 5 racks shown at left has 4 Type "FR" and 1 Type "PR" rack. Equal height racks may be intermixed with 19" and 24" wide panels. The end panels of the assembly have the detachable sides installed. They are quickly removable.

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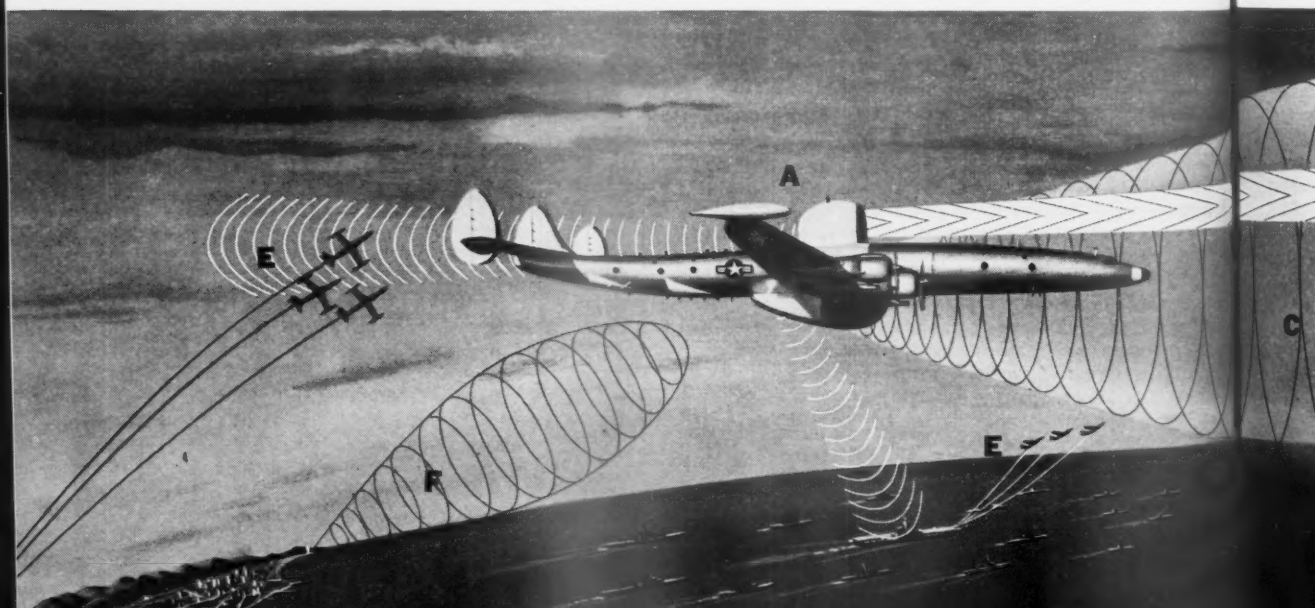
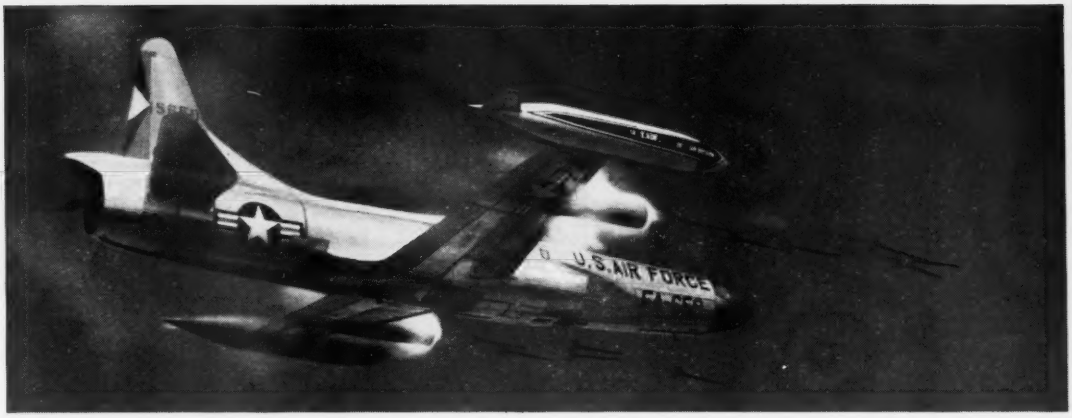


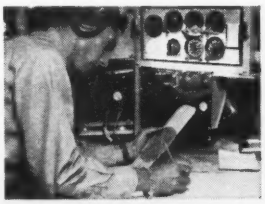


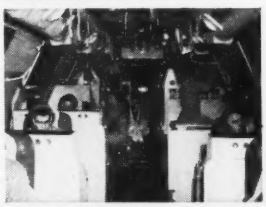
LEFT—EARLY-WARNING RADAR PATROL. Designated the WV-2 by U.S. Navy and EC-121 by USAF, these radar-domed Lockheed Super Constellations carry six tons of electronics and a 31-man crew. Super Constellations are ideal for this duty because of their famed all-weather stability and extremely long range.

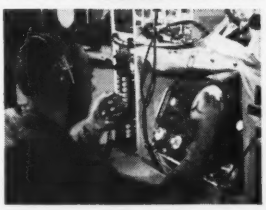
ABOVE—ROCKET-FIRING STARFIRE INTERCEPTOR. First of the almost-automatic all-weather interceptors, the Lockheed F-94C Starfire is an example of Lockheed's leadership in the design and development of airborne electronics. This deadly defender and other interceptors will soon be supplemented by—

Farsighted Pentagon planning and recent amazing technological developments by U.S. science and industry are rapidly making our nation's TOTAL DEFENSE system the most formidable in all history.

Lockheed's role in implementing our new Weapons System concept and in Systems management, is an important one. Thousands of Lockheed military aircraft, of *nine* widely different types, are already in service. Other advanced planes, missiles and electronic guidance devices are in production, undergoing tests or on the drawing boards at Lockheed. And Lockheed's pioneering leadership in design and development of airborne electronics will continue to contribute heavily to TOTAL DEFENSE.







STILL-SECRET F-104 SUPERSONIC JET FIGHTER. (Photo not yet released.) A high-ranking USAF officer said of the F-104: "This is a fighter pilot's dream. We feel confident that it is the fastest, highest-flying fighter in the air, anywhere."

THREE PHOTOS AT LEFT show crew members of Super Constellation early-warning plane at work. (Top) Navigator plotting a fix; (center) observers at radar consoles plotting altitude, speed and course of unidentified aircraft; (bottom) fighter-director charting position and path of approaching aircraft.

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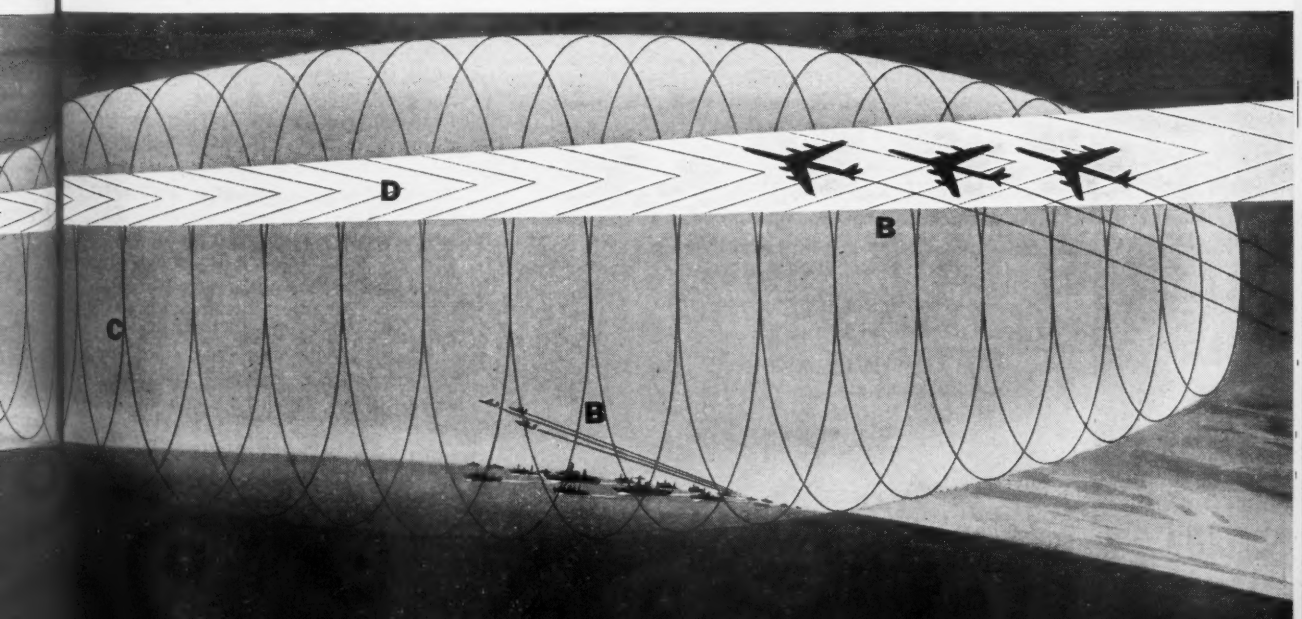

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AMPHENOL is actively engaged in current miniaturization programs: new Micro-Ribbons are the latest result. Other contributions are Subminax RF connectors and Miniature AN-type connectors. All are considerable engineering feats for all represent a *reduction in size and an increase in reliability.*

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improve their scheduled flight times from west to east.

Dr. Kuettner described the mountain wave as a vertical oscillation of the flow of air from the west to east, occurring after the air passes over mountain ranges. This oscillating flow or wave may require something between 50 to 100 miles to damp out beyond the mountain range.

There appear to be three distinct types of flow corresponding to three different altitudes. The highest type is in the stratosphere where the wave motion closely approximates or follows the contours of the mountain range up to the easterly extent of the range and then continues oscillating normally from there on out over the plains. At an intermediate altitude, the wave motion shows approximately 180° phase shift with respect to the mountain contour. At lower altitudes, the flow is violently turbulent in the valley area following the mountain range in which considerable flow rotation is present. This is the so-called rotor region.

Dr. Kuettner and his associates on the Air Force project studied the flow characteristics in these three different levels in the vicinity of the Sierra Nevada range, using gliders so instrumented that they could observe vertical motions and temperature changes. They were equipped for altitude operation which permitted them to carry their cross-sectional studies up to and above 42,000 ft.

On one of these flights, Dr. Kuettner experienced trouble in getting his glider down from an altitude of 42,000 ft. because his dive brakes and spoilers were frozen. On another occasion, one of his associates flew his glider into a cloud formation in the rotor region, and the glider was destroyed by the violent turbulence in that area. Fortunately the pilot escaped but only after being subjected to an estimated 20g acceleration for 0.4 sec.

Dr. Kuettner feels that definite flight hazards are involved in flying through the mountain wave areas because of the large variations of forward speed and altitude that may be caused within a short distance traveled. In addition, the turbulence level at lower altitudes may be severe enough to cause structural damage even to modern transport designs. Attempts at forward-speed control by automatic devices resulted in wild fluctuations in altitude in flying through the wave region. Corresponding attempts to control the altitude resulted in sharp speed variation which nearly produced stalling of the airplane.

Typical cloud formations in the vicinity of the rotor and the general mountain wave region were shown in a number of excellent slides. Statistical data on the turbulence levels, as well as

cross sections of velocity, pressure, and alititude, were also shown. Dr. Kuettner concluded this discussion by showing a 10-min. movie produced through the cooperative efforts of the University of California at Los Angeles, the Air Force photography branch, and the Museum of Science. This movie showed the equipment used in the studies, the gliders, the methods of launching the gliders, and in-flight views of cloud formations.

ARTHUR W. GILMORE, *Secretary*

San Diego Section

The San Diego Section joined 25 other societies and groups to participate in National Engineers' Week, February 19–25. Some of the activities during the week included working with the city and county schools and the San Diego State College in providing technical data and publications and a counseling service to teachers and in presenting discussions on the engineering profession before student groups. Considerable publicity was obtained in the local San Diego papers presenting the role and the work of the engineer in San Diego. Television movies and radio recordings were broadcast during the week on several local stations.

The following IAS members participated on the various Engineers' Week committees: C. L. Bates, Student Committee, City and County Schools; James Bowyer, Student Committee, Colleges; Roy T. Nilsen, Publications; W. T. Immenschuh, Speakers' Committee; J. C. Ramsey, Radio and TV Committee; D. P. Germeraad, Finance Committee; and W. Nugent, Special Projects Committee. The Engineers' Week Committee participated in the dedication of a new Engineering Building at San Diego State College.

The high social event of the week was a banquet held on February 21, attended by over 700 engineers, their wives, and guests. Toastmaster of the evening was John Bate, Port Director, Port of San Diego. A short address was made by Malcolm Love, President of San Diego State College, and the principal address was given by Joseph T. McNarney, President of Convair, A Division of General Dynamics Corporation. His talk covered the role of engineering in industry, and he discussed the shortage of engineers and suggestions to correct this condition.

Another major event of the week was a dinner meeting on February 24. Sir John Slessor, Marshal of the Royal Air Force (Ret.), formerly Chief of Air Staff 1950–1953, spoke on the subject "Strategy of the West." This meeting was presented under the auspices of the English Speaking Union with the cooperation of the SAE, ASME, ARS, and

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a statement by DR. L. N. RIDENOUR, *Director of Research, Lockheed Missile Systems Division*

Electronics is central to the technology of guided missiles. Dramatic improvements in missile performance require faster, more accurate perceptions and reactions of electronic missile guidance and control systems.

Here at the Missile Systems Division of Lockheed, we are aware of this requirement. We also know that electronics is experiencing the greatest revolution in its history; the vacuum tube, hitherto the cornerstone of electronic design, is being replaced by new solid-state devices which have superior performance and reliability.

Thus the times favor a bold approach to missile electronics. Past techniques will not meet requirements of the future. Experience in old-fashioned electronics is no great qualification for the present challenge. By giving the broadest responsibility to scientists and engineers, we are trying to lay proper emphasis on the new electronics.

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The field of missile systems is literally a new technology. No field of science offers greater scope for achievement.

Engineers and physicists will be interested in new developments at Lockheed Missile Systems Division.

A. A. Daush and senior members of the technical staff will be available for consultation at the Dayton Biltmore Hotel. For interview phone Adams 2161.

NEW
RESEARCH
CENTER
ANNOUNCED

Plans for new research laboratories at Stanford University's Industrial Park, Palo Alto, California, have been announced by Lockheed Missile Systems Division. Construction is underway.

Lockheed

MISSILE SYSTEMS DIVISION

IAS in recognition of Engineers' Week.

Because of the excellent cooperation of all the societies and groups participating in Engineers' Week, it proved to be a great success in the San Diego area. It is planned that this will be an annual event to present to the public and to the schools in the area the role of the engineer in this technological era.

▶ "Development of a Liquid-Cooled Gas-Turbine Engine" was the subject of a paper presented at the Technical Meeting on February 7 by Sumner Alpert, Project Engineer, and Ralph Grey, Experimental Engineer, Solar Aircraft Company. The paper discussed the application of internal liquid cooling to the rotor and blades of the gas turbine. The speakers showed how this allowed the turbine inlet temperature to be increased and alloys low in strategic materials to be used. Also outlined were the benefits possible with liquid cooling, the design of engine components being used in Solar's work, and the results of tests. On display were some of the liquid-cooled parts used in their program.

R. A. FUHRMAN
Corresponding Secretary

Traffic Control

San Francisco Section

Weldon E. Rhoades, Manager of the Flight Engineering Division of United Air Lines, Inc., spoke at the February 23 meeting. His subject was "Air Traffic Control—Present and Future."

Mr. Rhoades said the major problem confronting air transportation today, both civil and military, is air traffic control. The current methods are archaic, and the future traffic control problem will become even more difficult as the number of airplanes flying increases. The present control system requires individual following of each aircraft, and the monitoring must be done by a large staff in the control group.

The major objective of any traffic control system should be to move the maximum number of airplanes into and out of an airport in the most expeditious manner and with safety. Because the problem is four dimensional, it is impossible for control operators to visualize the location of all aircraft simultaneously. In fact, it is difficult for operators to visualize any more than a two-dimensional situation.

Mr. Rhoades believed the problem of aircraft traffic control could be solved technically. He pointed out that there should be three basic components for a satisfactory system. One would be a ground observing unit which would show the location of all aircraft within a given area; the second a requirement that all aircraft in the area transmit continuously their exact location to another ground unit; the third, a computer to analyze and direct traffic.

These two means of positioning aircraft would be used for comparative purposes and to note discrepancies.

Therefore, if there were a failure of a component in one system, the aircraft location would still be known by the other system. It has been estimated that the development of a system of this type would take from 6 to 10 years.

Because of the long delay in the engineering of such a control system, it is necessary that all concerned agree immediately on the specific approach to the design of the air traffic control system. Simultaneously, the money necessary to sponsor the development would have to be provided. The Federal Government has recently recognized the importance of this problem and is taking active steps to coordinate the development of a satisfactory air traffic control system.

In a high-density control area, the democratic system of the right to land at a specific airport will probably have to be modified. For example if a jet air liner from London with minimum fuel reserve is approaching the New York area for a landing at the same time a private pilot wishes to land a small aircraft, who should take precedence? It appears that the right to land must be designated to a certain extent.

J. A. BERT, *Secretary*

Seattle Section

The February 15 dinner meeting was held at the Sand Point Naval Officers Club. Bill Taylor, Chairman, presided at the meeting. Bob Bateman, Program Chairman, introduced the speaker, Herman L. Meyer, Assistant Project Engineer at The Glenn L. Martin Company. "The SeaMaster Story" was the topic of his lecture.

Mr. Meyer was particularly qualified to speak about the XP6M-1 SeaMaster, having been Aerodynamics Project Engineer on this giant jet seaplane. Mr. Meyer holds a B.S. degree in Mechanical Engineering and an M.S. in Aeronautical Engineering from M.I.T. He served as a B-26 pilot during World War II.

He started his lecture by comparing the SeaMaster to the Martin Mars seaplane (the Mars was chosen because it is in the same weight class). The smaller wing span, greater aerodynamic cleanness, and the nose design were some of the obvious factors in the pictorial comparison. In the past, propeller clearance above the water had been a major problem. With the advent of jet engines, however, the general seaplane configuration has changed. Mr. Meyer further stated that he be-

Members of the Texas Section and the Texas Soaring Association hear Alexander M. Lippisch, Director of Collins Aeronautical Research Laboratory, discuss methods of visualizing airflow. Dr. Lippisch designed the German ME-163, the first rocket-propelled interceptor.

lieves the next step in seaplane design will be the elimination of the wing-tip floats.

Movies of taxi and take-off tests of the SeaMaster were shown. Mr. Meyer made further comments on the T-tail design, directional control in the water, and nacelle arrangement.

▶ Following dinner in the plant cafeteria, the January 18 meeting was held in the Boeing Engineering Theater. The program consisted of a play, "A Wing Is Born," written by Robert L. Wahlborg, MIAS.

Larded with subtle humor, it was a story about how a jet wing could have been designed. It portrayed the situations and problems encountered in designing a jet wing from the time of preliminary Air Force orders, through design and testing stages, to the first flight of the jet transport. The cast and production staff were members of Boeing's KC-135 Stress Wing Group.

Bob Wahlborg took the part of the Stress Wing Group Leader. The other actors were Jim Hoy, Dave Espey, Lee McGee, John Claus, Arlin Laier, and Jack Wood. The stage staff consisted of Don Savage, Gary Prior, Paul Kollmeyer, Bill Zinke, Sharon Figg, and Gerry Sawyer.

▶ At the December 19 dinner meeting, Raymond L. Bisplinghoff, AFIAS, Professor of Aeronautical Engineering at M.I.T., repeated the Wright Brothers Lecture. After his presentation of "Some Structural and Aeroelastic Considerations of High-Speed Flight," three Boeing engineers took part in a prepared discussion. The panel consisted of L. M. Hitchcock, Staff Engineer—Structures; E. Z. Gray, Stress Unit Chief; and M. J. Turner, Structural Dynamics Unit Chief.

▶ Angus Jacks, Customer Requirements Engineer (Navy) of Convair, A Division of General Dynamics Corporation, spoke at the November dinner meeting. In his talk, "The Convair VTO," he elaborated on some of the problems of the control system of the delta-wing Pogo. Movies were shown containing shots made in the NACA Free-Flight Tunnel at Langley Laboratory and at free-flight trials inside the giant Navy dirigible hangar at Moffett Field. Mr. Jacks also discussed some of the general problems characteristic of all vertical take-off planes.

ELAINE GETHING, *Secretary*

Texas Section

The Texas Section of the IAS and the Texas Soaring Association conducted a joint meeting February 8 in the Arlington State College Engineering Auditorium. Alexander M. Lippisch, Director of Collins Aeronautical Research Laboratory of Collins Radio Company, addressed the audience of 250 persons on "Flow Visualization as a Tool in Aerodynamics."

The lecture, which was illustrated with slides and high-speed motion pictures, concerned several different types of investigation of flow visualization, techniques used to make flow visible, and equipment used in the investigations, such as the two-dimensional and three-dimensional low-turbulence tunnels.

Dr. Lippisch also spoke on his new concept of flight exemplified by the Aerodyne, a wingless aircraft which would utilize a lift-inducing propulsion system to obtain vertical and transitional flight.

C. L. TURNER, *Secretary*

Transonic Tunnels

Tullahoma Section

Principal speaker at the February 21 meeting was Hugh Gardenier, who discussed "Transonic Wind Tunnels." The talk was illustrated with a motion picture entitled *Increasing the Effectiveness of Wind Tunnels*.

The introductory portion of the talk was devoted to the early history of transonic testing techniques and the history of development of the transonic wind tunnel as such. In a general way, Mr. Gardenier discussed the contributions to the techniques of transonic testing made by Langley Aeronautical Laboratory of the NACA, the Research Department of United Aircraft Corporation, and Cornell Aeronautical Laboratory, Inc.

The speaker described the general design philosophy and the ultimate capability and use of the Arnold Engineering Development Center's Transonic Propulsion Wind Tunnel.

Mr. Gardenier pointed out that the Transonic Propulsion Wind Tunnel embodied the chief features of various other testing facilities, along with the design contributions to the art which were developed at AEDC and evolved principally out of the work done in the AEDC's Transonic Model Tunnel.

Of these contributions, the method of three-dimensional shock wave cancellation at the tunnel wall was, according to Mr. Gardenier, the contribution of paramount importance. The actual techniques, however, could not be discussed for reasons of security.

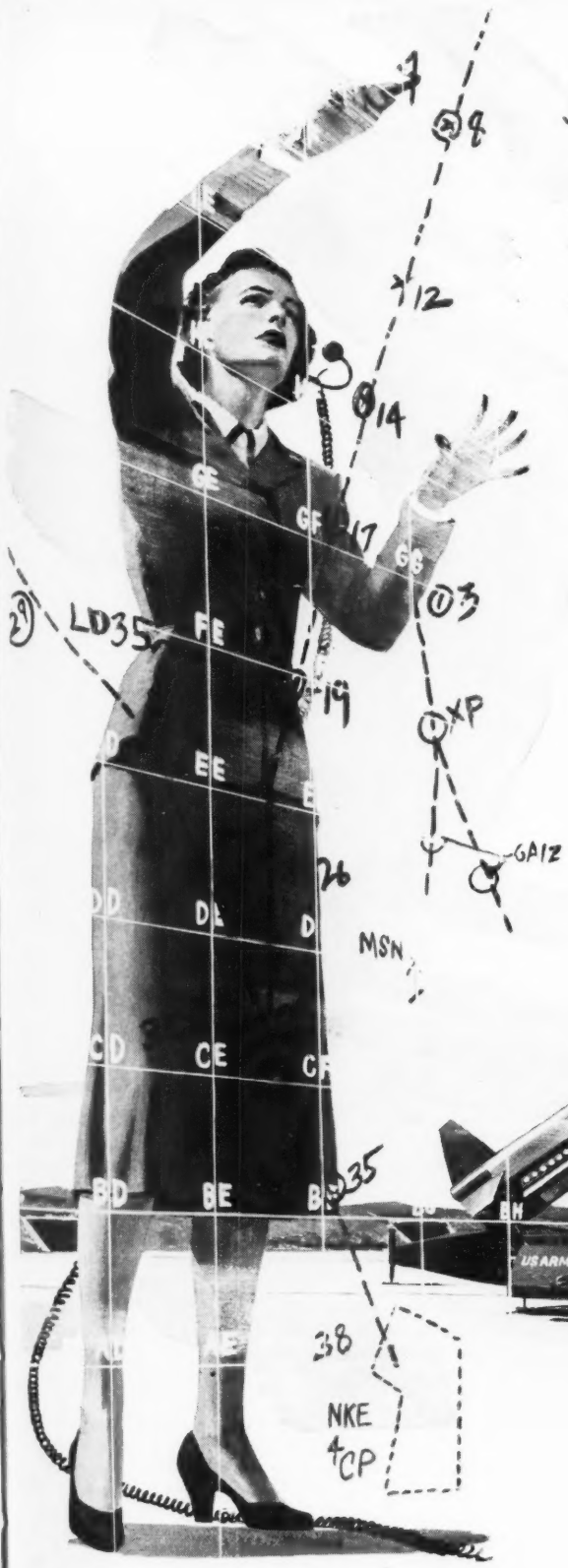
The lecture was concluded with a discussion of the ultimate facility capabilities and the testing programs to be carried out in the Transonic Propulsion Wind Tunnel.

E. A. SANLORENZO, *Secretary*

Change of Address

Since the Post Office Department does not as a rule forward magazines to forwarding addresses, it is important that the Institute be notified of changes in address 30 days in advance of publishing date to ensure receipt of every issue of the *Journal* and *Review*.

Notices should be sent directly to the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.



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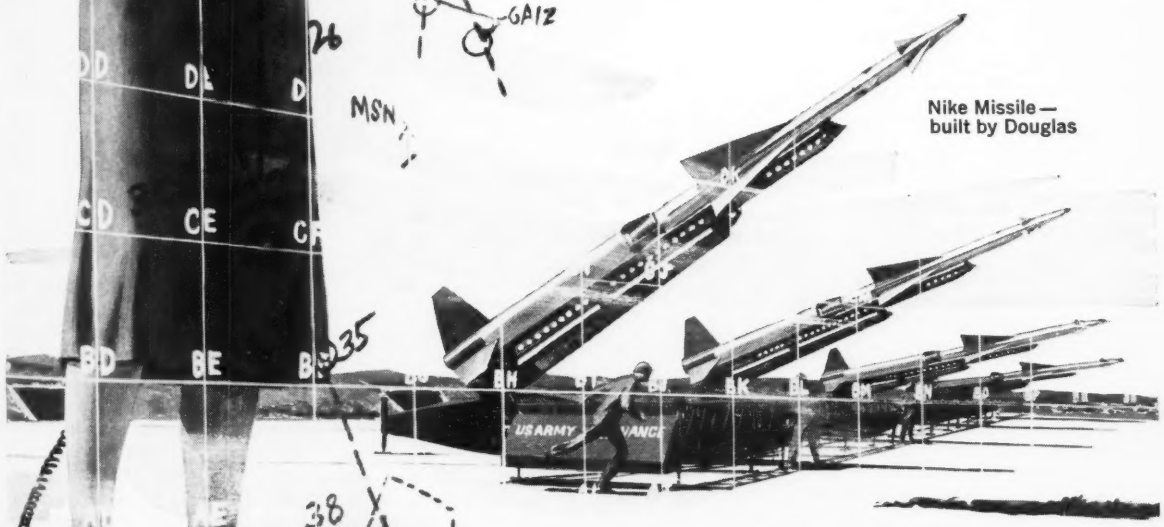

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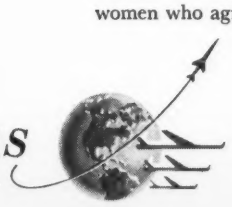
Depend on *DOUGLAS*  **First in Aviation**

STUDENT BRANCHES

Crash Fires

Agricultural and Mechanical College of Texas

Twenty-two members saw the film *NACA Crash-Fire Research* at the February 14 meeting. It was a graphic report on tests made by the National Advisory Committee for Aeronautics on decommissioned aircraft such as the C-82 and C-46 to study methods of decreasing fire hazards in a crash.

The tests consisted principally of accelerating the airplane on a runway to ground speeds encountered in take-off and landing operations and guiding the airplane into a barrier to simulate crash conditions. For each test the aircraft was instrumented to study various effects, and each run was photographed for detailed study.

Two primary sources of fires were discovered. The first was the ignition of fuel vapor coming in contact with hot engine and exhaust components and with the aircraft ignition system. The second source was the ignition of spilled liquid fuel by sparks caused by contact of the air frame with the ground or by spark-producing contact of air-frame components.

Studies regarding the first source indicated characteristics of fuel mixture flow, both internally and externally. The external flow distribution, according to the film, was dependent on the deceleration of the aircraft after the crash impact but was generally spanwise and forward. Internal flow of fuel, and fuel mixture, was found to be the result of structural members acting as channels to conduct the explosive mixture directly toward ignition sources.

Spark ignition fires resulted from combustion of spilled liquid fuel. The ignitible fuel area was found usually to be small except in wind-protected areas.

Three forms of fuel spillage—liquid fuel, fuel mist, and combustible vapor—were pointed out, with the spark-ignition fires related to the first type and the contact fires generally limited to the latter two types.

An internal fire-extinguishing system was developed which was seen to be highly effective in reducing contact fires, particularly near the engines. Where possible, structural design eliminating members conducive to internal flow of free fuel was recommended. Landing approach procedures calling for the shutting off of as many electrical devices as safety allowed also was recommended.

HARLESS R. BENTHUL, *Secretary*

Alabama Polytechnic Institute

Jack Bean, of the Aerodynamics Section of Convair's Fort Worth Division, spoke at the February 21 meeting on "The Aeronautical Engineer in Industry." He gave our embryo engineers an idea of the magnitude and variety of problems that arise during the development of a modern prototype airplane.

▶ David Reid, Assistant Administrative Engineer of Republic Aviation Corporation, spoke at the February 7 meeting on the problems arising from "Friction Heat at High Speeds." Mr. Reid pointed out that, even though great strides have been taken in the field of metallurgy, much more research is needed before materials will be available for tomorrow's aircraft designs.

Discussed in business meetings were plans for a field trip, furnishing of the IAS lounge, papers to be submitted to the IAS student conference in Atlanta, plans for a dance, and static displays for the annual campus open house, "Village Fair."

CHARLES F. HOLLEMAN
Publicity Chairman

California State Polytechnic College

Grant Hansen, Supervisor of Missile Electronic Equipment, Douglas Aircraft Company, Inc., spoke at the February 16 meeting. He outlined the missile program that Douglas has conducted since World War II. Mr. Hansen showed movies that he had taken at one of the V-2 launchings at White Sands Proving Ground shortly after the war.

Following his talk, the question-and-answer period brought to light many interesting aspects of missile defense. Among these was the question of the possibility of an antiballistic missile. The reply was that Douglas is hard at work on such a program.

Something a little different, in the way of social activity was initiated by the Program Committee. Plans were laid for an IAS Smoker with a choice of pizza or steak for dinner. An exchange skit between the students and the aero instructors proved to be the highlight of the evening: Students portrayed the instructors, and the instructors, in turn, gave their impressions of stereotyped aero students. The reaction of the 75 members present indicates that the Smoker may become an annual affair.

ELMER J. BISHOP, *Reporter*

Illinois Institute of Technology

Two hundred students attended the IAS meeting February 17 to hear a talk on "The ABC's of Rocket Propulsion" by Gerald M. Platz, Chemical Engineer, of the Armour Research Foundation.

Mr. Platz began his talk by summarizing the different types of propulsion and explaining the basic differences between jet and rocket propulsion. He discussed various solid rocket propellants and the many different forms that have been experimented with in attempts at obtaining even burning throughout the complete propellant charge. He mentioned many compounds and mixtures used in both solid and liquid rocket propellants and talked of the use of some of these as fuels for the V-2 and the Nike. Mr. Platz also covered several types of ignition system used with liquid propellants. These included the glow plug and the hypergolic reaction type, the latter type using two liquid fuels of such properties that they ignite upon contact with one another.

The following officers have been elected for the spring semester: Chairman, Erwin V. Zaretsky; Vice-Chairman, Gary Theis; Treasurer, Victor P. Vidugiris; Recording Secretary, Nominee Robinson; and Corresponding Secretary, Ralph W. Bourne, Jr.

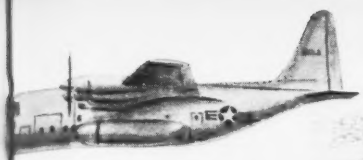
RALPH W. BOURNE, JR.
Corresponding Secretary

Gas Turbines

Iowa State College

A joint meeting of the student branches of the IAS and the American Society of Mechanical Engineers heard an address by Lewis A. Rodert, Special Projects Assistant of the Lewis Flight Propulsion Laboratory of the NACA, on "Reliability of Gas-Turbine Engines." At this meeting, held on February 21, Mr. Rodert was introduced by George K. Serovy of the Mechanical Engineering Department, who had formerly worked with him at the Lewis Laboratory.

Mr. Rodert reviewed some of the results of a study recently completed by the NACA on the reliability of gas-turbine engines and outlined some of the problem areas in the field of gas-turbine propulsion. He covered the topics of creep and stress rupture, mechanical fatigue, thermal distortion and thermal fatigue, and foreign-object damage. Mr. Rodert was assisted in his discussion of these topics by slides and a



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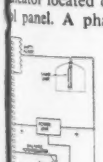

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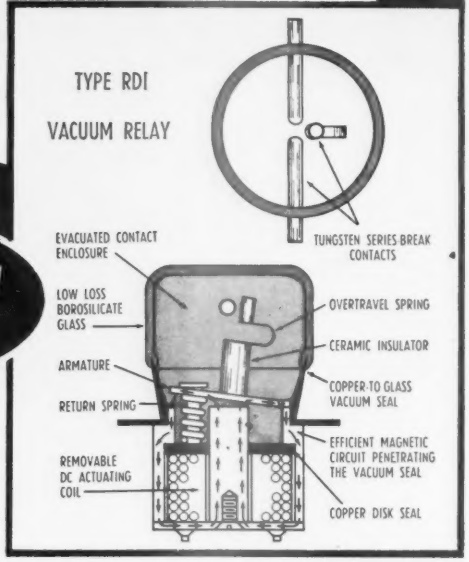

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6-min. movie entitled *Foreign-Object Ingestion by Vortices*.

Mr. Rodert stated that the problems requiring the most attention in the area of creep and stress rupture were ways to improve cooling, manufacture of better high-temperature alloys, design of better controls, and development of a low-temperature engine. In the area of mechanical fatigue, he mentioned the problems of detection of impending failures, improvement in cleanliness of alloys, selection of materials with good damping qualities, avoidance of repeated loads, and improvement in tolerance of rotor blades to nicks and scratches.

Means of cooling the engine was again mentioned as a problem in the area of thermal distortion and fatigue, as were selection of high-temperature alloys, segmenting of parts, and combining of materials able to withstand high temperatures and high stresses. The last area considered by Mr. Rodert was foreign-object damage, in which the main problems are design of adequate screens and building of compressors that are not sensitive to nicks and scratches. An interesting point which Mr. Rodert emphasized was that entry of foreign objects into the compressor was the leading cause of failure or unsatisfactory operation of jet engines.

ROBERT DIGHTON, *Secretary*

Kansas State College

Preston Dixon, Aerodynamicist of Beech Aircraft Corporation of Wichita, Kan., talked to the Student Branch February 23 about the new jet trainer being developed and tested by Beech. Mr. Dixon discussed the test phases and the aerodynamic characteristics of the aircraft. He stated that its maximum speed was about 295 m.p.h., while its landing speed was expected to be about 65 m.p.h. His talk to the group was illustrated by diagrams drawn on the blackboard. The company hopes that the new Model 73 will satisfy the needs of the Armed Services for a basic jet training plane.

Accompanying Mr. Dixon were Roy F. Kunz and Mr. Nagel of the Personnel Department of Beech. Mr. Kunz spoke briefly, pointing out the need for graduate engineers in the aircraft industry and also emphasizing the need for these engineers to develop their ability in oral and written expression, as well as in the more detailed technical aspects of engineering.

▶ The February 13 meeting was devoted to motion pictures. One showed the development of the new Lockheed T2V-1 trainer. The second film, *Frontier to Space*, was furnished by the physical science laboratory of the State College of New Mexico. It dealt with the

many problems still to be conquered in order that we may realize space flight. Three short films on flight safety also were shown. These were furnished by the Olathe Naval Air Station.

An IAS member is chairman of the Aero Option Display for Engineers' Open House this year. Coordinating with the Design Option, Craig Birtell will show the public the part aircraft will play in "Your Automatic Tomorrow," the theme for this year's Open House. As part of the display, Fred Suellentrop, President of the K-State Student Branch of the IAS, is preparing a working model of a three-stage rocket.

NOR SUTTON, *Secretary*

Separation

Mississippi State College

The Student Branch heard a talk on "Separation Control in Nature" by Joe Cornish of the Aerophysics Department, Mississippi State College, at the February 23 meeting.

Mr. Cornish first presented the basic theory of boundary-layer separation, pointing out the parts played by the pressure gradient and turbulence in the fluid flow. Many analogies were used to enable the freshmen and sophomores to grasp the basic principles involved. In concluding the theoretical part of his speech, Mr. Cornish pointed out that boundary-layer separation could be controlled or delayed by changing the pressure gradient, by turbulizing the boundary layer, or by changing the energy of the boundary layer.

In nature, the bird's wing evolved with a thickened leading edge, thus changing the pressure gradient and delaying separation. A mounted bat was used to illustrate this point. It was shown that the bat's wing contains two bones at the leading edge, instead of one as might be expected. The feather formation on a dove wing was shown to accomplish the same purpose. A feather formation on the leading edge of the dove wing was shown to act to delay separation much the same as slats on modern aircraft wings. It was pointed out that most soaring-type birds (such as the vulture) have this device.

All species of the owl, with one exception, have serrated feathers which turbulize the boundary layer, thus delaying separation and giving the bird a quieter flight. Quiet flight is necessary for the owl since it locates its prey principally by sound instead of sight. The one species of owl not having serrated feathers preys on fish. A tape recording of boundary-layer sound was run to show the difference in sound between a laminar and a turbulent boundary layer.

Mr. Cornish next presented a film showing the movement of the leading-

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edge stagnation point with a change in angle of attack and the condition of the surface flow when separation occurs.

In conclusion, Mr. Cornish summarized the various means employed by man to prevent or delay separation. It was pointed out that the only method used by man which nature is not known to use is the method of so-called boundary-layer control, which employs a suction on the boundary layer. Considerable experimental work is currently being conducted in this field by the Aerophysics Department at Mississippi State College.

Chairman Dixon extended the group's thanks for the interesting topic presented by Mr. Cornish. Ten committees were appointed to work on different projects to be presented in the Engineering Section of the State College Festival, March 23, 24.

NACA Research

▶ On February 14, a joint meeting of the IAS, ASME, and IREE was held in the Library auditorium, with 40 students present. Chairman Dixon introduced the speaker, S. Walter Hixon, Jr., Training Officer of Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics.

Mr. Hixon first presented a movie entitled *Research for Tomorrow's Aircraft* which outlined the NACA's research accomplishments and projects of recent years. Following the movie, Mr. Hixon expounded on the historical achievements of the NACA, pointing out that the Collier Trophy had been won on four occasions, the most recent one being awarded for the development of Whitcomb's area rule.

Mr. Hixon then discussed the present NACA test facilities and those proposed for the near future. A few of the items mentioned were a wind tunnel with temperatures up to 3,500° F. and velocities of Mach 2; a 19-ft. tunnel being repowered to give a complete range of transonic speeds (this tunnel is to be filled with freon gas), the purpose of which is to study vibration and flutter in the transonic region; a helicopter tunnel capable of testing tip velocities of 1,500 ft. per sec. and forward velocities of 350 m.p.h.; hypersonic tunnels capable of reaching Mach 7; a million-pound structures testing machine; and a spin tunnel for testing stability of models.

The graduate study program of the NACA was described in detail by Mr. Hixon. He pointed out that an M.S. degree can be obtained in 2 years with full pay throughout the period. He emphasized the growing importance of graduate study in all fields of engineering today.

JULIUS H. LOVE, *Secretary*

North Carolina State College

Axel T. Mattson, Head of the NACA's 8-Foot Transonic Wind Tunnel at Langley Aeronautical Laboratory, spoke at the February meeting on "The Development of Experimental Techniques for Transonic Research."

Mr. Mattson covered the subjects of free-fall models, rocket testing, wing-flow technique, the research airplane program, and the transonic tunnel itself. With slides and charts, he pointed out the advantages and disadvantages of each and also the correlation in data taken by several of the different methods.

Several IAS members are working on a 7-ft. scale model of the B-36 to be exhibited at the Engineers' Fair in April.

KEITH E. VERBLE, *Secretary*

Northrop Aeronautical Institute

Speakers at the February 25 dinner were George N. Mangurian, Chief of Structures, and Roy P. Jackson, Chief Analytical Engineer, both of Northrop Aircraft, Inc.

Mr. Mangurian's subject was "What Lies Ahead in the Aircraft Structures Field?" The big problems facing structures engineers arise from metal fatigue, aeroelasticity, and aerodynamic heating, according to Mr. Mangurian. A highlight of his talk was a demonstration with inflated balloons and a dart which illustrated the failure of a fuselage by decompression. The first balloon responded to the dart with the familiar "pop," but the second was suitably reinforced and deflated slowly. A third balloon also deflated slowly after being punctured in a low-stress area at one end. Mr. Mangurian concluded with challenging remarks about new materials and methods for meeting structures problems.

Mr. Jackson told "What the Future Holds for Aeronautical Engineers." His crystal ball made use of published data plotted against time on semilog paper. Mr. Jackson said that, if these curves continue to be straight lines, 1970 can bring an operational speed of Mach 3 and an altitude of 100,000 ft. for military aircraft, with nuclear power providing unlimited range. His final prediction, also statistically founded upon a straight-line plot of data since 1940, brought startled gasps from students and smiles of satisfaction from their wives: Engineers starting today at $450 a month will make $3,000 a month in the 1970's! Mr. Jackson advised, however, that the road is going to be rougher and that the young engineer should continue his education to his maximum capacity to avoid a leveling off of his career.

Chairman Harold R. Wheelock introduced Dana Moran, NAI class of February, 1951, Loads Engineer at Northrop Aircraft, and Chairman of the Student Activities Committee of the Los Angeles Section of the IAS. Mr. Moran presented the IAS Scholastic Award to Robert J. Hilovsky, honor graduate of the December, 1955, class and now a Rocket Research Engineer for North American Aviation, Inc.

Richard C. Smith was introduced as the new Faculty Adviser, succeeding Frank E. Washburn. Mr. Washburn is now a Personnel Representative for Rex Division of the Garrett Corporation.

New officers elected for 16-week terms are Charles A. Yost, Chairman; Garland O. Goodwin, re-elected Vice-Chairman; Theodore A. Heinz, Corresponding Secretary; E. Leon DeLano, Recording Secretary; and Gregory H. Russell, Treasurer.

GARLAND O. GOODWIN
Vice-Chairman

Oregon State College

Roland White, Project Engineer of the Boeing Airplane Company, spoke on "The Aerodynamic Development of the 707" at a combined meeting of the mechanical engineering societies on January 31. He explained design problems and showed motion pictures of the first flight of the 707, the flying boom on both the KC-97 and the 707, and the cross-wind landing gear on the B-52.

The Student Branch is planning a field trip to Los Angeles in the spring.

L. G. MALCOM, *Vice-Chairman*

Parks College of Aeronautical Technology

Richard Neumann, a student, spoke on "The Afterburner" at the March 1 meeting. After his talk, a film on the mining and fabrication of aluminum was shown.

The following new officers have been elected: Chairman, Galen Johnston; Vice-Chairman, Dale Anderson; Secretary, Gerald Panek; and Treasurer, John McCooey.

GERALD J. PANEK, *Secretary*

Purdue University

R. R. Heppe, Head of the Aerodynamics Section of Lockheed Aircraft Corporation, gave a lecture on "Current Design Problems of High-Speed Transport Aircraft" before an audience of 45 students at the February 23 meeting.

Mr. Heppe pointed out that the air transport companies, in their vast operations of today, are demanding aircraft with more cruise horsepower and

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larger pay loads. He used slides to show that the major domestic airlines of the United States make approximately 5,500 flights per day and that the largest number of take-offs and landings are made on flights of less than 1,000 miles. He indicated that, if a transport is to operate at a profit, it must be capable of operating effectively from short runways and over relatively short ranges.

Mr. Heppe pointed out that the Lockheed Electra was designed with these facts in mind and discussed the engineering difficulties encountered in designing the Electra to these criteria. Two movies were shown: *Lockheed Highlights—1955* and *Rocket Firing with the F-94C*.

▶ On February 14, the Purdue Student Branch held a call-out meeting to enroll new members for the spring semester. The meeting was attended by 100 guests and members.

Chairman Rittenhouse introduced the new officers and outlined the activities planned for the spring semester, with particular reference to the banquet to be held on March 12 at which M. J. Zucrow of the Purdue Rocket Laboratory will be guest speaker.

The rules governing the IAS student paper competition were explained. The meeting closed with a movie, *Target: Peace*, and refreshments.

DELBERT D. HOFFERTH, *Secretary*

Rensselaer Polytechnic Institute

James L. Decker, a graduate of R.P.I., class of '44, addressed the February 29 meeting on "Automatic Control in Modern Aircraft and Missiles."

Mr. Decker, who is now with The Glenn L. Martin Company, discussed the five main items of automatic control: stabilization, guidance, stability augmentation, control feel, and the autopilot. The first two of these items, he explained, pertain to missiles, while the last three are primarily for piloted aircraft.

Using block diagrams and the roll axis as an example, Mr. Decker explained an entire stabilization and control procedure. He also described the mechanism of hydraulic boost and "stick-feel" systems.

▶ At the February 15 meeting the speaker was G. W. Brewer, Assistant Head of the Boundary Layer and Helicopter Branch of the NACA at Langley Field, Va. His speech was entitled "The Role of the Wind Tunnel in Aeronautical Research." Mr. Brewer began with the history of wind-tunnel research and the many problems that had to be overcome. He stated that most of these problems have been solved, and their solutions have yielded valuable data.

In his discussion, Mr. Brewer noted many contributions of the wind tunnel in compiling airfoil data, drag cleanup, stability and control, engine ducting, and the Whitcomb area rule. Primary research must still be done in the fields of flutter, aerodynamic heating, and propulsion and airplane integration.

PETER D. TANNEN
Assistant Secretary

San Diego State College

Del Thomas, a Convair aeronautical engineer and Chairman of the Student Activities Committee of the San Diego Section of the IAS, spoke on "Aerodynamics" at the February 28 meeting. In the discussion that followed, he remarked that many aeronautical engineers continue their studies to earn a Master's degree.

"The more education you have," he said, "the better the job you can do for your company."

The Student Branch is planning a trip to Miramar Naval Air Base. On Engineers' Day, February 22, the Branch exhibited a J-47 turbojet engine and several Convair models.

MICHAEL D. CHILCOTE, *Secretary*

Stevens Institute of Technology

This Student Branch, established last November, has adopted its constitution and taken its place with the other engineering societies on the campus. At the December 16 meeting, it was announced that members who do not attend at least half of the meetings will be dropped, and officers who fall under scholastic probation will be replaced.

Eighty men attended a tour of the Stevens Towing Tank sponsored by the IAS on December 14. They were given lectures and demonstrations on the handling, operation, and purpose of this facility for hydrodynamic research.

On November 16, Stevens Institute invited high school students to tour the campus and laboratories for a glimpse of what an engineering college is like.

The Student Branch prepared an exhibit and took an active part in this Open House.

Ten students participated in a tour of the Stratos plant of Fairchild Engine and Airplane Corporation at Bay Shore, Long Island, on December 8. They accompanied members of the New York Section.

GERARD FRIDSMA
Corresponding Secretary

Tri-State College

Commander Cook Cleland, who won the Thompson Trophy Race in 1947 and 1949 flying a modified Corsair, addressed the March 1 meeting. He talked about difficulties encountered in procuring and preparing airplanes for the National Air Races and similar racing events. He also explained the techniques required for rounding pylons at high speed and related some incidents that occurred during the 3-year period that he participated in the National Air Races.

New officers of the Student Branch are Ronald G. Moyer, Chairman; John F. Parks, Vice-Chairman; Edward S. Palmer, Secretary; and Donald G. Boyer, Treasurer.

Harnessed Lightning, an Allison film on jet aircraft engines, was shown at a recent meeting.

RONALD G. MOYER, *Chairman*

U.S. Naval Postgraduate School

The Student Branch met February 22 to hear Leonard E. Root, Director of the Development Planning Department, Lockheed Aircraft Corporation, discuss "Future Developments in Aviation."

Mr. Root stressed the importance of development planning with emphasis on coordination at the future requirement, economic, and scientific-engineering levels. His remarks were supported with slides showing the organization of the Lockheed Aircraft Corporation. The discussion pertaining particularly to "Future Developments in Aviation" was secret.

Fifty members and guests attended this meeting. Guests included faculty members and Naval Reserve officers of Reserve Research Company 12-8 of Monterey, Calif.

FRED S. DUNNING, JR.
Corresponding Secretary

University of Alabama

Jack M. Bean, a representative of Convair and a graduate of the University of Alabama, spoke on "The Aeronautical Engineer in Industry" at the February 23 meeting. C. H. Bryan outlined plans for the Student Paper Competitions in Atlanta and Dallas, Tex.

▶ Recruiting representatives from Boeing Airplane Company visited the campus February 16 to talk with senior engineers. A Boeing film, *Jet Tanker Dry Boom Tests*, was shown at this meeting. A film on the Lockheed C-130 was shown at another recent meeting.

New officers are William Caudle, Chairman; K. O. Ball, Vice-Chairman; J. O. Nichols, Secretary; and J. L. Herring, Treasurer.

J. O. NICHOLS, *Secretary*

University of Colorado

Student members heard a talk on the Viking missile by Leslie J. Sullivan, of The Glenn L. Martin Company, at the February meeting.

Mr. Sullivan discussed the problems of producing and launching the first several Viking missiles. A film was shown entitled *Horizons Unlimited* which showed the production and firing of the Martin Viking missiles.

HAROLD J. BARTLESON, *Secretary*

University of Detroit

The annual Aeronautical Award Dinner was held February 14 in the new Student Union Building. This event was organized and sponsored by the junior class in the Aeronautical Engineering Department for the purpose of presenting awards to seniors for outstanding achievement.

The Continental Aircraft Design Award is conferred annually for the best design of an airplane produced by a senior student in Aero Engineering. The trophy and cash awards are offered by the Continental Motors Corporation. First place in the competition was won by Enrico Patrone. The cash award was $125. A second prize of $75 was awarded to Alfred Strickfadden. Thomas Mahar submitted the third best design. Each of the three winning designs was of a jet-powered sport plane.

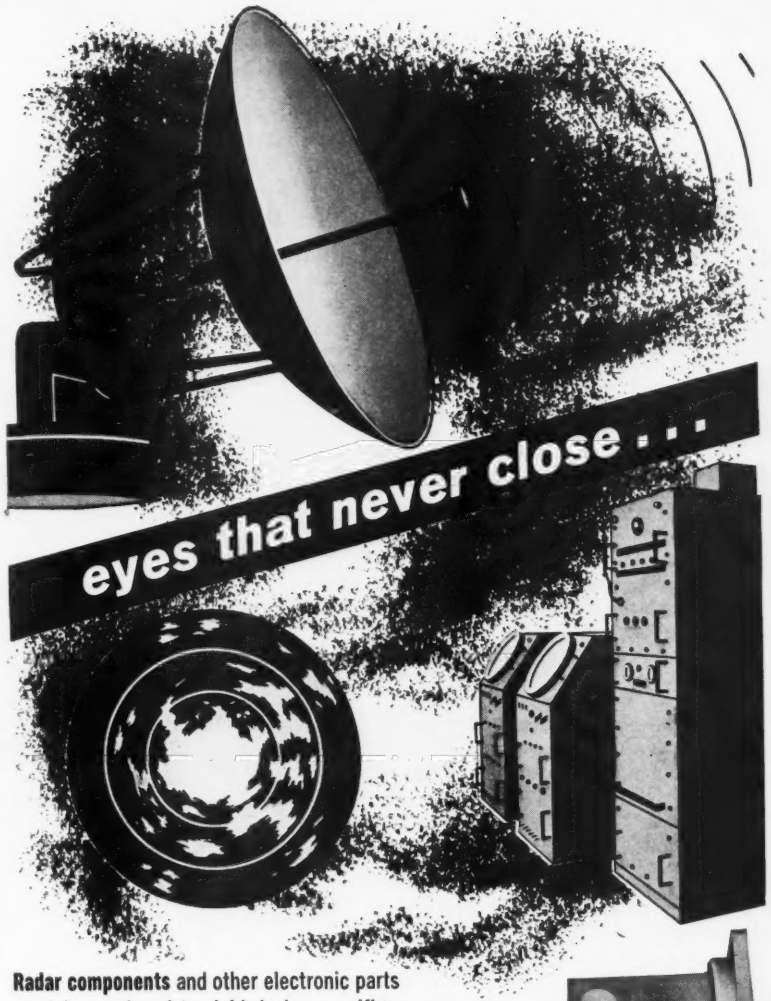
Judges in the competition were Guy Francois of Studebaker-Packard Experimental Division, Thomas Kelly of Smith-Morris Corporation, and Thomas Bowling of Studebaker-Packard. The presentations were made by James Shields of Continental.

The American Legion Award is a medal to be presented to the Aero Engineering student who attains the highest rating based on scholastic standing, high moral character, and citizenship. The award is offered by Aviation Post No. 257 of the American Legion in Detroit. Enrico Patrone was selected by several professors in the Engineering College as the winner of this medal. James Fisher made the presentation.

The guest speaker was Bob Housel of Engineering Flight Test, North American Aviation, Inc., Columbus Division. His speech covered the functions and problems of flight test as a division of an engineering organization.

Professor William P. Godfrey of the English Department in the Engineering College was the Master of Ceremonies. Also present were Prof. K. E. Smith, Chairman of the Aeronautical Engineering Department and Prof. E. A. Szczepaniak, IAS Faculty Adviser.

HILARY CHEETER, *Reporter*



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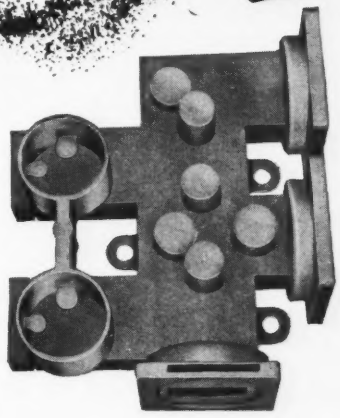

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University of Florida

Chairman Joe Tulino opened the February 20 meeting with a discussion of the membership drive. Each active member was assigned a prospective member to contact and inform about the advantages of IAS membership. He will be held responsible for bringing his assigned prospect to the next IAS meeting.

A decision was made for the Florida Branch to sponsor a research project dealing with the topic of static lift. At each meeting, two students will be asked to gather information on this topic and make a 10-min. report during the following meeting. At the end of the semester, all the reports will be combined into one article and submitted to either the *Florida Engineer* or an IAS magazine. Allen Ross was assigned to report during our next meeting on the basic history of static lift.

Plans for the Honors Night Banquet to be held in the Florida Union on May 11 were discussed. At this time, in addition to the usual lecture and scholastic awards made to graduating seniors, one freshman, one sophomore, and one junior will be selected for awards on the basis of personal accomplishments during this semester.

After the business meeting, a talk was made by Lt. Col. Lambert of the Wright Air Development Center on the subject of "A Synopsis of Work at Wright-Patterson." During this talk Col. Lambert described the functions of the Aircraft Laboratory to which he has been attached. He went into detail about the special projects division of the Aircraft Laboratory and described some of the recent work that has been done on escape ejection systems.

JOHN DAVID ANDERSON
Recording Secretary

University of Kentucky

Student members and guests heard a talk by Henry Epple, Vice-President—Engineering, of the Irving Air Chute Company, on "Bailing out at Supersonic Speeds" at the February meeting.

Mr. Epple outlined the problems involved when the necessity arises for a pilot to leave his plane while traveling at speeds of Mach 1 or more. He pointed out the things that must be considered in the design of parachutes to meet the demands of present-day aviation. Mr. Epple stated that one of the major problems is not with the parachute itself but with the devices and means to get the pilot safely out of his plane and down to altitudes where the parachute can take over. Also included in the talk was a discussion of the experiments performed in England with an ejection seat and parachute which can get a pilot out of his plane successfully while the plane is at extremely low altitudes or even on the ground.

Roy Baldwin was appointed Program Chairman to succeed Leonard Bennett.

WALTER J. BLACKSON, *Secretary*

University of Maryland

Raymond T. Patterson, Head of the Supersonic Division at David Taylor Model Basin, spoke on this Navy hydrodynamics laboratory and its mission at the March 6 meeting. He discussed recent changes and new equipment, mentioning the new 7-by-10-ft. transonic wind tunnel and the Lark electronic computer. Mr. Patterson showed a film on David Taylor Basin to supplement his discussion of current problems under study there.

Chairman Charles Stouffer outlined plans for the IAS Middle Atlantic Student Conference to be held here April 13, 14 and the Engineering Ball scheduled for May 4.

George Maggos, Faculty Adviser, described the benefits of IAS membership to five new members at the February 14 meeting.

HERBERT E. HUNTER, *Secretary*

University of Michigan

The Student Branch group photo for the school yearbook, *The Ensian*, was made at the February 14 meeting.

Two films were shown, *Wings for the Navy* and *Exercise Test Drop*, which were borrowed from Douglas Aircraft Company, Inc.

ROBERT R. JONES, *Secretary*

University of Minnesota

Mr. Blatt, of AiResearch Manufacturing Company, spoke on "Survival at High Altitudes" at a recent meeting.

Too many people, he said, take the atmosphere for granted. They live below 5,000 ft. altitude and do not realize the large pressure and temperature variations at altitude. He described the various levels of the atmosphere and conditions existing at each level. Pressurization is the answer to the problem of decreased pressure. The upper limit of aircraft as we know them today, he said, is 100,000 ft.

Mr. Blatt also discussed the problems that would be involved in building and establishing a manned satellite to circle the earth. The satellite would have to make its own gravity.

MARY JANE JUNG, *Secretary*

University of Southern California

Gilbert W. Magill, President of Rotor-Craft Corporation, spoke on "Small Helicopters" at the December 12 meeting. He showed movies of his new helicopter design, the Pin Wheel.

The Pin Wheel, which carries one person, is propelled by rockets mounted at the tips of the rotor blades. The hydrogen peroxide used as fuel must be pumped from the fuel tank to the rockets, a distance of about 10 ft. The unusual flying machine contains no transmission, thus reducing the friction and noise typical in conventional helicopters. Moreover, not one gear or electric wire can be found in the entire system. The Pin Wheel weighs 165 lbs., has a top speed of 70 m.p.h., and has been flown at an altitude of 9,000 ft.

New officers are Mike Hall, Chairman; Don Schlosser, Vice-Chairman; Paul Messinger, Secretary; and Jake Goldman, Treasurer.

GILBERT HERRERA, *Secretary*

University of Virginia

"The Area Rule" was the title of a talk given by James E. Sieling, a second-year aeronautical student, at the February 20 meeting. Mr. Sieling's talk was based on his paper describing the principles underlying the recent work of Richard Whitcomb, of the NACA at Langley Field, Va., on the "Coke bottle" configuration. This configuration reduces the wave drag of high-speed planes and permits easier passage though the transonic range. Mr. Sieling will present his paper at the Middle Atlantic Conference in April.

Vice-President Boyd Carr outlined plans for the Engineering Open House scheduled for April 27, 28. Among the displays will be a partially covered J-3 Piper Cub intended to show the structure and control system of a light plane.

In May there will be a field trip to Langley Aeronautical Laboratory to attend the NACA's Triennial Inspection there. We recently visited The Glenn L. Martin plant in Baltimore.

ALLAN D. SUMMERS, *Secretary*

University of Washington

Ken Bourke, Senior Meteorologist of Northwest Orient Airlines at the Seattle-Tacoma Airport, spoke on "Flight Operations" at the February 23 meeting.

He emphasized the necessity for teamwork and understanding between the air-line meteorologist, the air-line dispatcher, and the flight crew. The duties and responsibilities of each party were clearly defined. The speaker exhibited weather charts and forms and explained some of the weather symbols and phenomena by analyzing a weather map.

A Northwest Airlines flight from Seattle to Honolulu served as an example for the planning and execution of a typical air-line flight. Mr. Bourke discussed the many problems confronting flight personnel from the time the meteorologist prepared a preliminary forecast for the trip until the plane touched down in Honolulu.

GILBERT LEE
Recording Secretary

University of Wichita

L. E. Huffman and H. F. Bean, of Temco Aircraft Corporation, described employment opportunities for engineers at the February 20 meeting. They discussed the type of work at the Dallas plant, some problems confronting beginners, and opportunities for an engineer to continue study while working.

DUANE E. CHICHESTER,
Secretary

University of Wyoming

George Woodhead and Richard Johnston have been elected by the Student Branch to represent the IAS on the Engineers Joint Council. Three films were shown at the February 8 meeting, including *Stainless Steel*, issued by the Bureau of Mines.

JOHN C. FROST, *Chairman*

West Virgina University

The following officers have been elected for the spring semester: Chairman, Donald Peters; Vice-Chairman, Richard Walters; Secretary-Treasurer, Thomas Murphy; and Corresponding Secretary, Kenneth R. Conn.

The Student Branch has contributed $15 toward the deficit of the Engineers' Ball. The other engineering societies also are contributing in proportion to membership.

RAY HERRING
Corresponding Secretary (Ret.)

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Appold, Norman C., M.S. in Ae.E., Col., USAF; Chief—Power Plant Lab., WADC, Wright-Patterson AFB.

Transferred to Associate Fellow Grade

Compton, Philip R., M.S. in Ae.E., Asst. Chief—Advanced Design Sect., Douglas Aircraft Co., Inc. (Long Beach).

Foss, Clifton T., B.S., V-P & General Mgr., Arma Div., American Bosch Arma Corp.

Kempner, Joseph, Ph.D., Assoc. Prof.—Aero. Engrg., Polytechnic Institute of Brooklyn.

Lessard, Roy W., B. of Ae.E., Chief—Tech. Engrg., Fairchild Aircraft Div., Fairchild Engine & Airplane Corp.

Lothrop, G. William, B.S. in Ae.E., Sr. Engr., Liquid Racket, Aerojet-General Corp.

Patton, Robert J., M.S. in Ae.E., Sr. Aerodynamics Group Engr., Convair, Fort Worth, A Div. of General Dynamics Corp.

Elected to MEMBER Grade

Ackerman, James S., B. of Ae.E., Aerodynamics Engr. "A," Northrop Aircraft, Inc.

Anderson, J. Edward, M.S.M.E., Research Proj. Engr., Aircraft Dynamics Sect., Research Dept., Minneapolis-Honeywell Regulator Co.

Arne, Vernon L., B.S. in Ae.E., Devel. Design Engr., Chance Vought Aircraft, Inc.

Becker, Charles Z., B.E.E., Asst. Regional Mgr.—Application Engrg., Summers Gyroscope Co.

Boldt, W. Felix, Asst. Proj. Engr., McDonnell Aircraft Corp.

Charleville, Joseph L., B.S., Design Engr., McDonnell Aircraft Corp.

Elcan, William C., B.S., Mgr.—Electric Equipment Sales, Central District, Aviation & Defense Indus. Sales Dept., General Electric Co. (Dayton).

Fielding, Peter G., Special Proj. Sr. Design Engr., Lockheed Aircraft Corp. (Marietta).

Finger, Harold B., M.S. in Ae.E., Assoc. Head, Compressor Research Branch, Lewis Flight Propulsion Lab., NACA.

Fitzpatrick, Mary A., M. A., Struct. Engr., Missile Systems Lab., Sylvania Electric Products, Inc.

Flodin, Len O., B.A. in Business Admin., Assoc. Research Engr. "A," Boeing Airplane Co. (Seattle).

Gregory, Edgar W., II, M.S., Air-Borne Weapon Systems Engr., Jet Engine Dept., AGT Div., General Electric Co.

Helgeson, Gordon E., Flight Test Proj. Engr., North American Aviation, Inc. (Los Angeles).

Hoffman, George A., Sc.D. in Applied Mech., Engr.—Structural Analysis, The RAND Corp; Lecturer, Engrg. Extension, University of California (Los Angeles).

Johnson, Richard E., B.S., District Mgr.—Aviation & Defense Indus. Sales Dept., General Electric Co. (Wash., D.C.).

Johnston, George S., M.S.E., Sr. Struct. Engr., McDonnell Aircraft Corp.

Kesilis, Stanley P., M.S. in Ae.E., Design Specialist-Lead Engr., Loads Group, Missile Systems Div., Lockheed Aircraft Corp.

Kimura, Arata, B.S., Supvr., Analytical Sect., Pratt & Whitney Aircraft Div. United Aircraft Corp.

Longmire, Darrel C., Designer "A," Aircraft Struct., Douglas Aircraft Co., Inc. (Tulsa).

Miller, Leon G., Group Design Engr., McDonnell Aircraft Corp.

Morris, James J., Aviation Safety Agent, Civil Aero. Admin., ASDA (La-Guardia Field).

Mutchler, Lynn D., B.S., Group Supvr., Stress Dept., McDonnell Aircraft Corp

Northup, Robert W., M.S. Engrg. in M.E., Devel. Engr., Aircraft Engines, Turbo Motor Div., Curtiss-Wright Corp.

O'Hern, Eugene A., Ph.D., Supvr., Flight Control Sect., North American Aviation, Inc. (Downey).

Paraghamian, Berg, M.S.M.E., Design Engr., Aerodynamics, The Glenn L. Martin Co.

Peterson, Richard A., B. of Ae.E., Struct. Engr., North American Aviation, Inc. (Los Angeles).

Quest, Roland, M.S., Liaison & Test Engr., McDonnell Aircraft Corp.

Romano, Marinus A., M.A.E., Sr. Aerodynamicist, Republic Aviation Corp.

Schmitt, Donald E., B.S. in M.E., Design Engr., McDonnell Aircraft Corp.

Schoenky, H. Parnell, B.S. in M.E., Flight Test Instrumentation Engr., McDonnell Aircraft Corp.

Sealander, Bertram E., B.S., Staff Engr. Electrical Systems, Republic Aviation Corp.

Smith, Donald G., Sr. Aircraft Design Engr., Lockheed Aircraft Corp. (Marietta).

Steinmetz, Harold F., B.S.M.E., Chief Aerodynamicist, Missile Aerodynamics Dept. Missile Engrg. Div., McDonnell Aircraft Corp.

Stroukoff, Oleg, M.S., Asst. Proj. Engr., Advanced Design, The Glenn L. Martin Co.

Tunstall, Reginald V., B.S. in AeE., Flight Test Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Wadleigh, Calvin D., B.S. in Ae.E., Proj. Flight Test Engr., McDonnell Aircraft Corp.

Wakefield, Charles W., B.S.E.E., Military Coordinator, Military Sales Dept., Missile Systems Div., Lockheed Aircraft Corp.

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Wen, William L., M.S. in Ae.E., Dynamics Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Willett, Jack R., B.S., Lab. Engr., Analyst, Applied Math. Dept., McDonnell Aircraft Corp.

Wilson, Herbert W., B.S., Sr. Design Engr., North American Aviation, Inc. (Downey).

Wimberly, Donald C., B.S.M.E., Asst. Mgr., Aviation Div., Wholesale Dept., Standard Oil Co. of California.

Yount, T. L., Electronics Group Engr., McDonnell Aircraft Corp.

Zambon, Louis B., M.S. Aero., Mgr.–Engrg., Jet Engine Dept., General Electric Co. (Cincinnati).

Transferred to MEMBER Grade

Benefield, Tommie D., B.S.Ae.E., Capt., USAF; Experimental Flight Pilot, Air Force Flight Test Center, Edwards AFB.

Blackburn, Albert W., M.S. in Ae.E., Engrg. Test Pilot, North American Aviation, Inc. (Los Angeles).

Chappell, David P., B.S.M.E., Stress Group Leader, Helicopter Div., McDonnell Aircraft Corp.

Christopher, John F., M.B.A., Sr. Engr., Product Utilization, The Glenn L. Martin Co.

Clarke, Joseph H., Jr., Ph.D., Asst. Prof.—Aero. Engrg., Aerodynamics Lab., Polytechnic Institute of Brooklyn; Consultant, North American Aviation, Inc.

Curry, Robert C., Proj. Engr., Aircraft Struct., American Airlines (Tulsa).

Desai, Pratap D., M. Ae.E. (Aero.), Aero. Engr., Hindustan Aircraft, Ltd.

Graham, Herbert R., B.Sc.Ae.E., Devel. Engr. "A," California Institute of Technology at the Southern California Cooperative Wind Tunnel.

Holt, H. Robb, B.S.M.E., Design Engr., Power Supplies Group, Navy Ordnance Div., Eastman Kodak Co.

Millett, Merlin L., Jr., M.S., Asst. Prof., Dept. of Aero. Engrg., Iowa State College.

Newland, James E., B.S., Engr., Struct., North American Aviation, Inc. (Los Angeles).

Piper, James E., B. of Ae.E., Sr. Dynamics Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Prasse, Ernst I., B.S., Aero, Research Scientist, Lewis Flight Propulsion Lab., NACA.

Scolatti, Charles A., B.Sc.Aero., Task Scientist—Hypersonics Research, Aero. Research Lab., WADC, Wright-Patterson AFB.

Socks, Glenn A., B.S., Stress Engr., Missile Branch, Chrysler Corp.

Ventura, Joseph J., B.S., Staff Engr., Ramo-Wooldridge Corp.

Elected to Associate Member Grade

Allen, Robert G., Pres. & General Mgr., Presco Products Div., Borg-Warner Corp.

Anderson, James R., Sales Engr., Cleveland Pneumatic Tool Co.

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Cook, H. Weir, Jr., District Mgr., Cook Electric Co.

Duffey, Lilah W., Proof Planner "A," Convair, San Diego, A Div. of General Dynamics Corp.

Macoosh, Gabriel S., Principal Asst., Aero. Standards, Dept. of Civil Aviation, Ministry of Transport & Communications, Tel-Aviv.

Randolph, Roland H., Lab. Production Engr., Physical Test Lab., McDonnell Aircraft Corp.

Richter, Harold C., Asst. Proj. Engr., Sverdrup & Parcel, Inc.

Rosenbaum, Leonard G., Field Supvr., Service Engrg. Dept., Apparatus Sales Div., General Electric Co. (Cincinnati).

Van Der Hoeden, A., Asst. Naval Attaché, HMS Netherlands Embassy (Wash., D.C.).

Elected to Technical Member Grade

Addison, Glenn T., Aircraft Systems Evaluation Engr., Devel. Dept., AGT Div., General Electric Co.

Baines, Harry B., Design Engr., Airframe Struct., McDonnell Aircraft Corp.

Baird, John J., B.S., Design Engr. "A," McDonnell Aircraft Corp.

Barakauskas, Edward, M.M.E., Student, Cambridge University (England), on leave of absence from Westinghouse Electric Corp.

Barton, Paul M., B.S., Layout Engr., McDonnell Aircraft Corp.

Beckett, Harry I., B.S., Flight Test Instrumentation Engr., North American Aviation, Inc. (Columbus).

Calahan, Hubert D., B.S., Flight Test Data Engr., McDonnell Aircraft Corp.

Dennison, John M., B.S., Flight Test Data Engr., McDonnell Aircraft Corp.

Eastham, James D., B. of M.E., Production Test Pilot, McDonnell Aircraft Corp.

Glasgow, John C., B.S., Struct. Engr., McDonnell Aircraft Corp.

Greenberg, Aaron J., B.S.C.E., Engr. "A," McDonnell Aircraft Corp.

Hanner, O. M., Jr., B.S. in Ae.E., Aerodynamicist, McDonnell Aircraft Corp.

Keil, William C., B.S., Aero. Engr., United Airlines, Inc. (San Francisco).

Kelly, Marianne, B.A. (Cum Laude), Tech. Analyst—Engrg., McDonnell Aircraft Corp.

Lee, Gerald D., Engr., Flight Test Instrumentation, McDonnell Aircraft Corp.

Newman, Herman M., B.S.C.E., Stress Analyst "A," Stress Unit, Boeing Airplane Co. (Seattle).

Roberts, Sanford L., B.S. in E.E., Test Engr., McDonnell Aircraft Corp.

Sweeney, Donald S., Design Engr., McDonnell Aircraft Corp.

Van Meter, George W., Engrg. Draftsman, Cessna Aircraft Co.

Vickers, Frank K., B.S., Layout Draftsman, McDonnell Aircraft Corp.

Walitzer, Warren C., B.S. in Ae.E., Struct. Engr., Airplane Stress Dept., McDonnell Aircraft Corp.

Szabo, John A., B.E.E., Engr. "A," McDonnell Aircraft Corp.

Transferred to Technical Member Grade

Aker, Irvin G., Sr. Layout Draftsman, Emerson Electric Co.

August, Arthur, Design Trainee, Grumman Aircraft Engineering Corp.

Bonser, Thomas G., B.S. in Ae.E., Engr., Internal Aerodynamics, North American Aviation, Inc. (Downey).

Boyd, Donald S., B.S. in Ae.E., Liaison Engr., Temco Aircraft Corp.

Chang, Che Tyan, Ph.D., Research Fellow—Hydrodynamics, Div. of Engrg. & Applied Physics, Harvard Univ.

Cohen, Edward C., B.A.E., Struct. Engr., Grumman Aircraft Engineering Corp.

Colgan, Richard L., B. of Ae.E., Customer Service Rep., Aero. Engrg. Co. Div., The Garrett Corp.

Culp, Richard B., Jr. Engr., Model Designer, Boeing Airplane Co. (Seattle).

Draim, John E., B.S. in Ae.E., Lt., USN; Post-Graduate Student, Naval Admin. Unit, Massachusetts Institute of Technology.

Favre, Harrison B., B.S., Flight Test Engr., McDonnell Aircraft Corp.

Funk, Donald D., B.S. in Ae.E., Assoc. Engr. "A," Stress Engr., Douglas Aircraft Co., Inc. (Tulsa).

Garodz, Leo J., B.S. in Ae.E., Lt. Comdr. & Naval Aviator, USN; Candidate for Master's Degree, Aero. Engrg. Dept., Princeton Univ.

Harrison, Ralph, Jr., B.M.E., Ens. USN.

Heineman, W., Jr., B.S., Weight Engr., Convair, Fort Worth, A Div. of General Dynamics Corp.

Higdon, Donald T., B.S.

Lam, Sau-Hai, B. of Ae.E.

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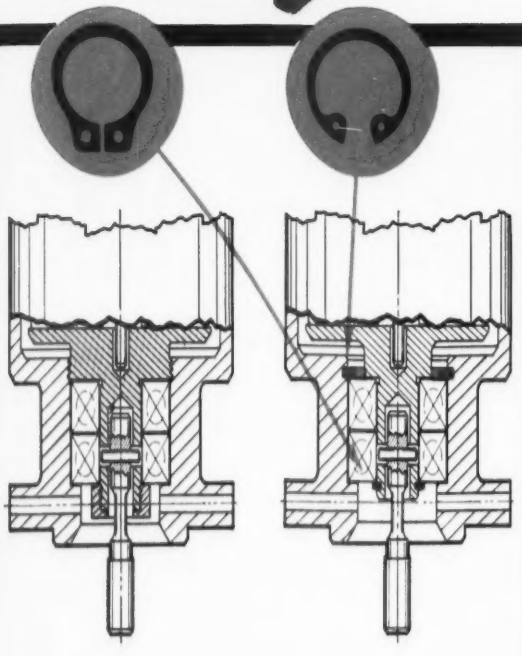
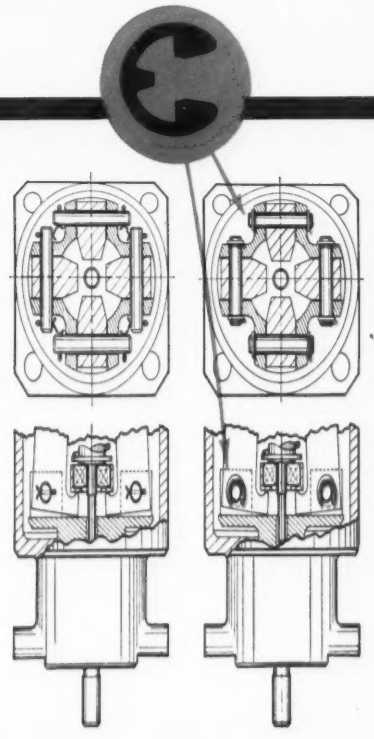


Rotor Installation. In the old way, ball bearing was retained by a threaded shoulder and threaded bearing cup retainer.

New way, using two Truarc Rings (Series 5100 and 5000) eliminates 4 threading operations, bearing shoulder and threaded bearing cup. Assembly is quicker and easier, two ounces lighter.



Flyweight Assembly. Formerly, 2 holes had to be drilled in each of the 4 pivots, and 8 cotter pins were required.

The new way, using 8 Truarc E-Rings (Series 5133), replaces holes with grooves, reduces pivot size, leaves no projecting parts. Rings snap into place, speed assembly time by three minutes per unit.

Whatever you make, there's a Waldes Truarc Retaining Ring designed to improve your product...to save you material, machining and labor costs. They're quick and easy to assemble and disassemble, and they do a better job of holding parts together. Truarc rings are precision engineered and precision made, quality controlled from raw material to finished ring. **36 functionally different types**...as many as 97 different sizes within a type...5 metal specifications and 14 different finishes. Truarc rings are available from 90 stocking points throughout the U. S. A. and Canada.

More than 30 engineering-minded factory representatives and 700 field men are available to you on call. Send us your blueprints today...let our Truarc engineers help you solve design, assembly and production problems...without obligation.

For precision internal grooving and undercutting ... Waldes Truarc Grooving Tool!

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maintenance stages in terms of the Calendar Aircraft Inspection and Repair (CAIR) overhaul program covering periodic inspections of specified areas, systems, and components, taking into account safety, operational efficiency, and economy factors.

The Short SB.6 Seamew A.S.I. *Brit. Aircraft Ind. Bul.*, Jan., 1956, pp. 4–19, cutaway drawings. Detailed aerodynamic, design, structural, and performance data, with descriptions of general characteristics, power-plant installation, and special features.

De Super Sabre—De North American F-100 C Super Sabre. *Avia Vliegwereld* (Netherlands), Jan. 19, 1956, pp. 34–37, cutaway drawing. Design, structural, and operational characteristics, with power-plant specifications.

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Summary of Scale-Model Thrust-Reverser Investigation. John H. Povolny, Fred W. Steffen, and Jack G. McArdle. *U.S., NACA TN 3664*, Feb., 1956. 49 pp. Study of the relative performance efficiency, other characteristics, and potentialities for aircraft control purposes of target, tail-pipe cascade, and ring cascade types, taking into account the effects of design variables and reversed-flow boundaries along with thrust-modulation parameters.

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Developing the Martin-Baker Ejection Seat. I, II. *The Aeroplane*, Feb. 3, 10, 1956, pp. 141–143, 168–171. Developmental appraisal of design and operational factors; potentialities.

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Some Aspects of the Design of a D.C. Amplifier for Use with a Slow Analogue Computer. H. Fuchs. *Electronic Eng.*, Jan., 1956, pp. 22–25. Application to the analysis of the equations of the ground-resonance problem affecting helicopter operation, with development of criteria for performance accuracy based on the parameters of gain, bandwidth, drift, grid, current, common h.t. resistance, and operational impedance errors.

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A Logarithmic Voltage Quantizer. E. M. Glaser and H. Blasbalg. *IRE Trans. EC Ser.*, Dec., 1955, pp. 150–155. USAF-supported experimental development of an automatic analog-to-digital converter design; applications and potentialities.

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High Density Williams Storage. S. Y. Wong. *IRE Trans., EC Ser.*, Dec., 1955, pp. 156–158. USAF-Army-Navy-supported experimental investigation at the Princeton Inst. for Advanced Study to determine a method of storing more bits on a Williams tube than by conventional techniques.

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Magnetic Core Circuits for Digital Data-Processing Systems. D. Loev, W. Miehle, J. Paivinen, and J. Wylen. *Proc. IRE*, Feb., 1956, pp. 154–162.

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(*Continued on page 196*)

INTERNATIONAL AERONAUTICAL ABSTRACTS

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PUBLISHED MONTHLY BY THE AERONAUTICAL ENGINEERING REVIEW

Official Publication of the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

Volume 1, Number 5 May, 1956

ACOUSTICS, SOUND AND NOISE

SUPERSONIC BANGS. PT. I. P. Sambasiva Rao. Aero. Quart., Feb., 1956, pp. 21-44. Development of a nonlinear theory of supersonic bangs from an accelerated body using an extension of the Whitham method, to determine the strength of the bow shock indicating the effect of acceleration on the pressure rise at large distances from the nose for Mach Numbers near unity. Results, as compared to those of the linear theory, indicate that the estimate for the pressure rise is about one-half of the linear value, and include an expression for the curvature of an attached shock at the nose and a formula for the decay of a shock after detachment from a decelerating body.

ACOUSTICS OF A NONHOMOGENEOUS MOVING MEDIUM. D.I. Blokhintsev. (Moscow, Gostekhizdat, 1946.) US, NACA TM 1399, Feb., 1956. 198 pp. 55 refs. Translation. Analysis of sound propagation and reception in a moving medium, including fundamental acoustic equations used in the theory of wave propagation from a moving source, particularly from a propeller, and in the following problems: the occurrence of vortical sound in the motion of bodies through the air; sound propagation in the atmosphere and water; a moving sound source such as a source at supersonic velocity, with details of the development of a ballistic wave of an artillery missile for a uniformly retarded and accelerated motion and a muzzle wave for an accelerated curvilinear motion of a distrubance source; a general formula for the Doppler effect; and sound excitation by flow and action of a sound receiver in a stream.

AERODYNAMICS

APPLIED AERODYNAMICS AND FLIGHT MECHANICS. W.B. Oswald. J. Aero. Sci., May, 1956, pp. 469-484. 16 refs. Analysis of the von Kármán investigations in terms of design applications as related to such specific problems as: turbulent skin-friction variation with Reynolds Number, turbulent skin-friction variation with Mach Number into the supersonic speed regime; pressure coefficient variation with Mach Number in the subsonic speed regime; transonic similarity rules for correlating information on thin bodies in the transonic speed range, and nose shape for optimum pressure drag of slender bodies of revolution at supersonic speeds. Includes: study of operating economy at high speeds; evaluation of recent investigations of ballistic vehicles and related problems of heating, hypersonic flow, superaerodynamics, and long-range ballistic flight.

HYDRODYNAMICS - A REVIEW OF VON KARMÁN'S CONTRIBUTIONS. A.T. Ippen. J. Aero. Sci., May, 1956, pp. 436-441, 499. 25 refs. Discussion of the boundary layer and turbulence concepts, von Kármán vortex trails, impact of seaplane floats on water, hydraulic analogy to supersonic motion, and developments in hydraulic machinery, based on previous investigations and as related to the problems of: predicting flow resistance and power losses in open and closed channels for hydraulically smooth and rough surfaces; flat plate drag; wave characteristics; oscillations induced in bodies exposed to fluid streams; the relations between the unsteady pattern of slamming loads and the elastic response of ship structure; the statistical properties of the wave patterns of the open sea; disk friction in hydraulic machinery; and of turbomachinery.

SOME PROBLEMS IN AERODYNAMICS AND THEIR SOLUTION BY ELECTRICAL ANALOGY. D. Küchemann and S.S. Redshaw. J. RAeS, Mar., 1956, pp. 191-197. 83 refs. Survey of aerodynamic phenomena including two- and three-dimensional airfoils, interference, and potential flow problems. Application of the analogous system: to determine the effect of the helical vortices of a propeller with a finite number of blades and the flow pattern in a centrifugal impeller; to obtain wind tunnel correc-

tions; to study axisymmetric contraction shapes, diffusers, cowlings, and air-intakes; to investigate the movement of water seeping through under hydraulic structures; to solve heat transfer and fluid flow problems obeying equations other than that of Laplace, and problems of viscous damping in small-diameter tubes, temperature distribution in a gas-turbine rotor, and wave-equation boundary-values; and to treat the flow in the holograph rather than in the physical plane.

Boundary Layer

THE THREE-DIMENSIONAL LAMINAR BOUNDARY LAYER FLOW ABOUT A YAWED ELLIPSOID AT ZERO INCIDENCE. Appendix I - THE VALUE OF THE PARAMETER IN THE STAGNATION-POINT FOR AN INFINITE ELLIPTIC CYLINDER. Appendix II. J.A. Zaat, E. Van Spiegel, and R. Timman. Netherlands, NLL Rep. F. 165, 1955. 20 pp. Calculations using the Timman theory as applied to the case of sweptback wings, with the momentum equations replaced by a set of two first order partial differential equations in two unknown functions. These functions are two parameters characterizing the velocity profiles in the direction of the streamline at the outer edge of the boundary layer, and in a direction parallel to the surface and normal to the streamline direction.

EIN VERFAHREN ZUR BERECHNUNG DER LAMINAREN GRENZSCHICHT MIT BELIEBIGER DRUCKVERTEILUNG AND WÄRMEÜBERGANG FÜR ALLE MACHZAHLEN. Kurt Werner Mangler. ZFW, Jan.-Feb., 1956, pp. 63-66. 10 refs. In German. Development of a numerical iterative method for the calculation of the laminar boundary layer for an arbitrary pressure and temperature distribution along the wall for any Mach Number, taking into account the dependency of the viscosity and the Prandtl Number on the temperature. Application to the study of the effects of various physical parameters on the solutions and on wall friction and heat transfer on the wall in order to obtain examples on which to base and test momentum integral methods.

RECENT INVESTIGATIONS OF THE PROBLEM OF TRANSITION. H.L. Dryden. ZFW, Mar.-Apr., 1956, pp. 89-95. 20 refs. Comprehensive summary of studies of the problem of transition from laminar to turbulent flow, with special emphasis on the generation of turbulence in an incompressible medium and on the stabilizing effect of cooling on the compressible boundary layer. Includes analyses of: NACA experimental results based on the Prandtl, Tollmien, and Schlichting fundamental findings; factors controlling transition; and the effect of Mach Number on transition on bodies without heat transfer.

THE RESISTANCE LAW FOR ROUGH PLATES. L. Prandtl and H. Schlichting. (Werft-Reederei-Hafen, Berlin, Jan., 1934.) US, Navy Dept., David W. Taylor Model Basin, Transl. 258, Sept., 1955. 13 pp. Development of a theory based on Nikuradze results of flow through artificially roughened pipes, taking into account those obtained by von Kármán on the frictional resistance, up to arbitrarily high Reynolds Numbers, of smooth, plane plates situated lengthwise to the flow.

SOME EXPERIMENTAL STUDIES OF THE SEPARATION OF SUPERSONIC TURBULENT BOUNDARY LAYERS. S.M. Bogdonoff. Princeton U. Dept. Aero. Eng., Rep. 336, June, 1955. 18 pp. 28 refs. Summary of ONR-ARDC-sponsored test results indicate that: the wall static pressure ratio at which separation occurs is approximately a linear function of Mach Number in the range from 1.35 to 3.85; strong changes exist in the interaction phenomenon when the separation region is small, and there are considerably higher static pressure gradients which reach a state of quasi-equilibrium when the separation region becomes of the order of a boundary layer thickness in height; the peak pressure ratios considered as a combination of the separation pressure ratio and an additional pressure ratio due to mixing indicate an increased effect of mixing with increasing Mach Number; and an approximately linear relation between the pressure ratios obtained before separation and Mach Number is considerably higher than the separation or the peak pressure.

SOME FEATURES OF BOUNDARY LAYERS AND TRANSITION TO TURBULENT FLOW. A.M. Kuethe. J. Aero. Sci., May, 1956, pp. 442-450, 506. 85 refs. Review of investigations of the problem, with experimental results on transition in Poiseuille flow in a tube, including measurements of the transition excited by the annular wake behind a ring airfoil and oscillographic recordings of the velocity fluctuations in the flow for several disturbance amplitudes. Includes analysis of the Howarth, Illingworth, and Stewartson investigations for the comparison of compressible velocity profiles with "equivalent" incompressible profiles transforming the compressible boundary-layer equation into a form identical with the incompressible equation, under the assumption of Prandtl Number unity, viscosity proportional to absolute temperature, and zero heat transfer.

GRENZSCHICHSTEUERUNG IN DER PRAXIS. G.V. Lachmann. ZFW, Jan.-Feb., 1956, pp. 9-14. In German. Critical analysis of methods existing or in development used to prevent boundary layer separation on airfoils and the increase of lift due to flaps by sucking or blowing. Includes an evaluation of fundamental factors concerning the practical application of suction to stabilize a laminar boundary layer; and of the influence of reduction of drag and weight on the direct operating costs of long range airliners.

FLUID FLOW IN REGIONS BOUNDED BY POROUS SURFACES. Geoffrey Taylor. Proc. Royal

Soc. (London), Ser. A, Mar., 6, 1956, pp. 456-475. Investigation of the aerodynamic effects of blowing air into or sucking away boundary layers, under the assumption that the rate of discharge through the pores is under experimental control, applied to the case of flow through a wedge, cone, and cylinder, with the resistance of the material proportional to the square of the velocity through it, using an integral equation. Results indicate that when all the fluid reaches the field of flow through the pores the pressure at any point in the field depends on the distribution over the porous surface of the flow through it, and the through-flow at any point of it depends on the pressure.

STABILITÄTSMINDERNDE EINFLÜSSE BEI ABSAUGEGRENZSCHICHTEN. Walter Wuest. ZFW, Jan.-Feb., 1956, pp. 81-84. 11 refs. In German. Analysis of the difference in theoretically predicted and experimental values for the considerable increase of stability limits of boundary layers by means of suction indicating such possible causes as: surface waviness, surface roughness, and the nonuniform structure of the suction. Development of a method for the calculation of the periodic boundary layer flow and its stability in the two-dimensional case of equally spaced suction slots.

Fluid Mechanics and Aerodynamic Theory

FLOW SEPARATION IN THREE DIMENSIONS. E.C. Maskell. Gt. Brit., RAE Rep. Aero. 2565, Nov., 1955. 20 pp. Development of a generalized concept of the separation phenomena, with a determination of conditions in the vicinity of the line of separation indicating that the resulting flow is composed of two basic elements: the free vortex layer; and the bubble identified as a characteristic pattern formed in the solid surface by the family of limiting streamlines.

BODIES OF REVOLUTION HAVING MINIMUM DRAG AT HIGH SUPERSONIC AIRSPEEDS. Appendix A - ESTIMATED EFFECT OF CENTRIFUGAL FORCES ON SURFACE PRESSURE COEFFICIENTS. Appendix B - CALCULATIONS OF MINIMUM-DRAG BODIES, WITH CONSIDERATION OF CENTRIFUGAL FORCES IN THE DISTURBED FLOW FIELD. A.J. Eggers, Jr., M.M. Resnikoff, and D.H. Dennis. US, NACA TN 3666, Feb., 1956. 38 pp. 18 refs. Theoretical and experimental investigation to determine approximate shapes of nonlifting bodies having minimum pressure foredrag. Includes calculations of: the various combinations of the conditions of given body length, base diameter, surface area, and volume, using the Newton law of resistance; and the additional effect of curvature of the flow over the surface to determine its influence on the shapes for minimum drag. Results indicate that: when body length is fixed the body has a blunt nose and when not fixed it has a sharp nose; the centrifugal forces in the flow about bodies curved in the stream direction may influence their drag; the relative extent of this influence is predictable, particularly at the high Mach Numbers, with a simple modification to the impact theory of Newton; and the resulting shapes are blunter in the region of the nose, have more curvature in the region downstream of the nose, and have slightly lower drag than the corresponding shapes obtained using the simple impact theory.

EXPERIMENTAL INVESTIGATION OF THE FLOW AROUND LIFTING SYMMETRICAL DOUBLE-WEDGE AIRFOILS AT MACH NUMBERS OF 1.30 AND 1.41. P.B. Gooderum and G.P. Wood. US, NACA TN 3626, Mar., 1956. 86 pp. 17 refs. Includes measurements of pressure and Mach Number distributions, lift and drag coefficients, center of lift, and pitching moment for various angles of attack up to 5°. Results, as compared to the small-disturbance and the shock-expansion theories using the transonic similarity laws, indicate that the pressure distributions on wedges of different thickness and Mach Number are similar at the same values of transonic similarity parameter and reduced angle of attack for angles as large as the thickness ratio; that the lift-curve slope is approximately independent of the angle of attack for a range from -2° to 2°; and that for airfoils tested at Mach Numbers greater than the attachment value the center-of-pressure location is nearly independent of the angle of attack, the variation being ± 3 per cent chord.

FORMATION OF A VORTEX AT THE EDGE OF A PLATE. Leo Anton. (Ing.-Arch., 1939, pp. 411-427.) US, NACA TM 1398, Mar., 1956. 36 pp. Translation. Investigation of the flow about a plate of infinite width represented as a potential flow with discontinuity surfaces extending from the plate edges applied to the case of a plate perpendicular to the approaching flow and forming a right angle, with results indicating that for prescribed form and vortex distribution of the discontinuity surfaces the velocity field can be calculated by means of a conformal representation.

AN INTEGRAL EQUATION THEORY FOR THE TRANSONIC FLOW AROUND SLENDER BODIES OF REVOLUTION AT ZERO INCIDENCE. F. Keune and K. Oswatitsch. Stockholm, KTH Aero TN 37 (Aug. 16, 1954), 1955. 78 pp. 14 refs. Application of the Oswatitsch method using the gasdynamic equation for axisymmetric transonic flow. A certain function is assumed for the variation in velocity at radial distances from the body. The integral equation is reduced to line integrals for calculating the velocity on the axis of the body, which are analyzed into finite sums of strips of equal width. Comparison of the linear and nonlinear subcritical flow which shows sufficient agreement up to high subsonic Mach Numbers.

INVISCID HYPERSONIC FLOW OVER BLUNT-NOSED SLENDER BODIES. Lester Lees. GALCIT Memo. 31, Feb. 1, 1956. 12 pp. 10 refs. Investigation of the applicability of Taylor and and Lin results of studies of the shape of bow shock-wave behind an unyawed, axially-symmetric body travelling

at a uniform hypersonic velocity to the problems of a shock-wave generated by a blunt nose of finite radius on an unyawed slender body. Results agree qualitatively with those of the Hammitt, Vas, and Bogdonoff experiments on a flat plate with a blunt leading edge in the Princeton helium tunnel.

A METHOD FOR CALCULATING THE CONTOUR OF BODIES OF REVOLUTION WITH A PRESCRIBED PRESSURE GRADIENT AT SUPERSONIC SPEED WITH EXPERIMENTAL VERIFICATION. Appendix A - EQUATION FOR DETERMINING THE FLOW PROPERTIES OF A FIELD POINT. Appendix B - METHOD OF DETERMINING THE TRANSITIONAL REYNOLDS NUMBER OF THE M = 3.13 NOZZLE. P. B. Burbank. US, NACA TN 3555, Mar., 1956, 64 pp. Development based on the theory of characteristics to compute the ordinates near the nose of a body as related to aerodynamic problems of body-wing interaction, inlets, boundary-layer transition, separation, and shock interaction using a model constructed with an initial included cone angle of 30° and a contour to provide a linear pressure distribution for a 3.13 free-stream Mach Number and tested at free-stream Mach Numbers of 3.05 and 3.13.

ASPECTS OF THE PROBLEM OF TURBULENT MOTION. C.C. Lin. J. Aero. Sci., May, 1956, pp. 451--459, 516. 81 refs. Survey of investigations with emphasis on the physical mechanism, including description of the intermittent nature of turbulent flow. Analysis of the statistical theory of turbulence along the lines of Taylor and von Kármán, and the theories of turbulent shear flow, taking into account: the transition from laminar flow to turbulence; general equations of homogeneous turbulence; approximate theories; self-preserving hypotheses; large and small eddies; and turbulent flow with velocity or temperature gradient.

EXPLORATORY INVESTIGATION OF THE TURBULENT WAKES BEHIND BLUFF BODIES. Appendix A - THE REYNOLDS EQUATIONS OF MOTION AND THE ENERGY EQUATION OF TURBULENCE DERIVATION. Appendix B - DERIVATION OF APPROXIMATE EQUATIONS OF FLUID MOTION. R.D. Cooper and Morton Lutzky. US, Navy Dept., David W. Taylor Model Basin, Rep. 963, Oct., 1955. 31 pp. 12 refs. Results of measurements of the mean velocity and the turbulence intensity of the axial component of the fluctuating velocity in the wakes behind a disk and a series of four rectangular plates agree substantially with theoretical results derived from similarity considerations for axially symmetric wakes. Results further indicate: that the maximum values of the mean velocity defect and the turbulence intensity vary inversely as $x^{\frac{1}{2}}$ where x denotes the axial position in the wake; that the radius of the wake varies as $x^{\frac{1}{2}}$; and that the transverse distributions of the mean velocity defect and the turbulence intensity are universal functions of $\eta = r/x^{\frac{1}{2}}$ where r denotes the radial position in the wake.

Internal Flow

IL CALCOLO DEI DIFFUSORI PALETTATI DE TURBOCOMPRESSORI CENTRIFUGHI (THE CALCULATION OF THE BLADED DIFFUSERS OF CE TRIFUGAL COMPRESSORS). G.L. Valdenazzi. L'Aerotecnica (Rome), Oct., 1955, pp. 267-277. 10 refs. In Italian. Investigation of the flow throu radial cascades to develop advanced design metho using two-dimensional theories of flow through straight cascades taking into account the three-dimensional effects.

AN EXPERIMENTAL INVESTIGATION OF A THICK-AEROFOIL NOZZLE CASCADE. S.J. Andrews and N.W. Schofield. Gt. Brit., ARC R&M 2883, 1956. 13 pp. BIS, New York. $1.00. Study of the flow over the blade sufaces applying the evaporation of crystals, lamp-black deposit, surface total-head measurement and stethoscope search tube methods to determine the transition point, with a calculation of the point of instability from the velocity and boundary-layer momentum-thickness distribution using the Polhausen criterion; and theoretical estimates of the effect of the thick trailing edg to evaluate the heat-transfer properties and efficiency of airfoil-section blades with the thickness maintained well toward the trailing edge. Results indicate that: the airfoil nozzle blade gives a good performance below an outlet Mach Number of 0.8 over a wide range of incidence, with the loss increasing steeply above that point and showing no signs of decrease with the approach of sonic speed below M = 0.8 the nozzle would be suitable for an internally cooled blade of a high-temperature turbine; the transition to turbulence on the blade with the cascade mounted at exit from an unlit combustion chamber begins at $x/c = 0.15$ from the trailing edge; and the loss due to the thick trailing edge is approximately 40 per cent of the total loss, assuming zero velocity immediately behind the trailing edge.

RESULTS OF SYSTEMATIC INVESTIGATIONS ON SECONDARY FLOW LOSSES IN CASCADES. I SECONDARY FLOW LOSSES IN COMPRESSOR CA CADES OF PROFILE NACA 8410. II - SECONDAR FLOW LOSSES OF A TURBINE CASCADE FOR DI FERENT VELOCITY PROFILES OF INFLOW. K. Gersten. Braunschweig Tech. Hochschule Inst. Strömungsmech., Rep. 54/29a, Rep. 54/12a, 1955. 62 pp. 15 refs. Results of USAF-sponsored experimental investigations on: profiles of solidity ratio = 1, 135° blade angle, and the ratio of blade length to blade chord = 3 at 4.10^5 Reynolds Number based on the outflow velocity as compared to two-dimensional flow conditions indicate the presence of regions with strong separation at the side walls producing a strong acceleration of the flow in the middle plane, decreasing the pressure rise across the cascade and preventing the flo separation on the blade in the vicinity of the middl plane; and on turbine cascades between parallel plane walls of solidity ratio = 1, 0, the ratio of blad

length to blade chord = 5, 135° inflow angle, and 35° and 45° blade angle at 9.10^4 Reynolds Number indicating the influence of the boundary layer thickness.

RANDVERLUSTE IN PUMPENGITTERN. Hermann Schlichting. ZFW, Jan.-Feb., 1956, pp. 35-40. 14 refs. Results of test measurements of flow losses in compressor cascades for the incompressible case and, in two-dimensional flow obtained by applying suction to the walls, of the effect of secondary flow along the walls on the pressure rise in the cascade as well as on the deflection of the flow for the ratio of blade length to blade chord $\ell/t = 3$. Results further indicate that the secondary flow effect in compressor cascades is much greater than in turbine cascades; and that a splitting up of the total losses into two-dimensional and additional secondary flow losses appears in many cases of turbine cascades, as compared to compressor cascades.

ROTATING STALL IN AXIAL COMPRESSORS. William R. Sears. ZAMP, Nov. 25, 1955, pp. 429-455. 16 refs. Review of OSR-sponsored investigations, based on linearized airfoil and channel relations of the rotating stall phenomena involving basically a nonuniform flow pattern, rotating steadily relative to both the fixed and the rotating blades of axial-flow compressors, and on the assumptions of a single row of closely spaced blades and the small perturbation type of flow. Includes an analysis of the applicability of the small-perturbation theories, with calculations of the linear and nonlinear lift coefficient curve, variable-area channels, and boundary-values. Results indicate that the self-induced rotating stall patterns occur in stalled, rigid blade rows; that stall flutter produces periodic flow patterns rotating around the blade annulus if the flutter frequency is not equal to rotational frequency; and that the stall flutter occurrence is intimately dependent on the elastic properties of the blade.

SURVEY OF INFORMATION ON TWO-DIMENSIONAL CASCADES. M.J. Schilhansl. USAF WADC TR 54-322, Mar., 1955. 175 pp. 138 refs. Review of the literature covering straight and radial cascades in terms of turbomachinery design requirements. Includes: a compilation of available theories classified as approximate or rigorous solutions; analysis of the effects of high turning angles, Reynolds Number variation, and compressibility effects.

THE THEORETICAL CALCULATION OF FLOW LOSSES IN A TWO-DIMENSIONAL CASCADE (ÜBER DIE THEORETISCHE BERECHNUNG DER STRÖMUNGSVERLUSTE EINES EBENEN SCHAUFELGITTERS). H. Schlichting and N. Scholz. (Ing.-Arch., No. 1, 1951, pp. 42-65.) Gt. Brit., MOS TIB/T4539, Nov., 1955. 33 pp. 30 refs. Translation. Application of methods for the determination of drag of an isolated airfoil to the study of flow losses as related to blade form, pitch, and angles of stagger, incidence and deflection and based on the Prandtl boundary layer theory, with calculations of the pressure distribution, the laminar or turbulent friction layer along the blade surface and the wake flow behind the blade.

PERTURBATIONS OF SUPERSONIC NOZZLE FLOWS. R.E. Meyer. Aero. Quart., Feb., 1956, pp. 71-84. Extension of the Meyer and Holt perturbation theory to general, steady, supersonic, two-dimensional, isentropic and irrotational flow of a perfect gas to determine, in terms of the nozzle design requirements, the effect on the velocity distribution in the test rhombus of a change in the stagnation pressure in order to change the Reynolds Number, or of a slight tilting of the liners to change the Mach Number slightly; and the error admissible in the estimate of boundary layer corrections and, generally, the tolerances admissible regarding the shape of the liners. Results indicate: that the error at any point of the liner is propagated along a path leading to the axis of symmetry back to a point further downstream; and that in the symmetrical perturbation flow the ratio of the error in Prandtl angle at the end of the reflection path to twice the original error in liner slope at the beginning of the path is given by a product of reflection factors λ, one for each reflection at the liner, with the value of λ rising from nothing at the first reflection point for errors originating near the throat to unity at the end of the liner. The Mach Number and pressure were obtained from the error in Prandtl angle by conversion factors.

Stability and Control

THE INFLUENCE OF TURBOJET AIRFLOW ON THE AERODYNAMIC DESIGN OF AIRPLANES. Harold Luskin and Harold Klein. Douglas Rep. SM-19111, 1955. 42 pp. 11 refs. Application of momentum and angular momentum theorems to determine the longitudinal forces and moments acting on a turbojet airplane. Analysis considers the effects of skin friction, pressure drag, scoop drag, jet tilt, inlet stagnation pressure losses, and outlet nozzle installation; and includes a discussion on particle aspiration, inlet airflow nonuniformity, and the problems of buffeting, heating, and noise caused by jets.

Wings and Airfoils

SOME PROPERTIES OF CURVED PLANFORMS FOR SWEPTBACK WINGS AT SUBSONIC AND SUPERSONIC SPEEDS. G.G. Brebner and W.T. Lord. Gt. Brit., RAE TN Aero. 2417, Nov., 1955. 17 pp. 16 refs. Summary of the subsonic theory of curved planforms and a presentation of results of preliminary investigations of the wave drag of several swept wings similar to subsonic designs. Results indicate that: at subsonic speeds the wing planform can be designed to have a required spanwise local-lift-coefficient distribution, applicable to the improvement of the longitudinal stability of sweptback wings at low speeds; and at supersonic speeds the wave drag of sweptback wings with curved planforms,

as calculated by linearized theory, varies with Mach Number in a more plausible manner than the wave drag of wings with straight-edged planforms.

KRITISCHE BEMERKUNGEN ZUR DREIDIMENSIONALEN TRAGFLÄCHENTHEORIE IM UNTERSCHALLGEBIET. H.G. Küssner. ZFW, Jan.-Feb., 1956, pp. 21-26. 13 refs. Analysis of methods for the approximate solution of the boundary value problem of the three-dimensional lifting surface theory in subsonic region; application to the elliptical lifting surface with infinite aspect ratio, assuming an incompressible fluid and a bilinear downwash distribution, with exact solutions for the lift and moments as compared to previous results.

SOME RECENT DEVELOPMENTS IN AIRFOIL THEORY. W.R. Sears. J. Aero. Sci., May, 1956, pp. 490-499. 43 refs. Review of investigations of: the theory of profiles with boundary layers in steady flow; the theory of profiles with boundary layers in unsteady flow, including extensions of unsteady airfoil theory; the theory of wings with leading-edge separation; and the Prandtl wing theory applied to partially stalled wings. Includes analyses of: the viscosity phenomena; the von Kármán and Trefftz generalization of the Joukowski transformation to produce families of airfoils having finite trailing-edge angles; the Prandtl lifting-line wing and the Munk thin airfoil theories; the von Kármán treatment of the lifting surface by Fourier-integral techniques; and the Howarth study of the lift of a thin elliptic cylinder at incidence by means of boundary-layer theory.

ZUR AERODYNAMIK DES RINGFLÜGELS IN INKOMPRESSIBLER STRÖMUNG. Johannes Weissinger. ZFW, Mar.-Apr., 1956, pp. 141-150. In German. Development of a method for the calculation of the pressure distribution over thin and nearly axisymmetrical annular wings in incompressible flow and of the appropriate forces and moments. The assumptions correspond to those in the theory of lifting surfaces applied to conventional airfoils. Includes results for the total lift and position of the aerodynamic center of the annular wing at incidence as a function of the chord-diameter ratio.

A REVIEW OF SOURCE SUPERPOSITION AND CONICAL FLOW METHODS IN SUPERSONIC WING THEORY. H.J. Stewart. J. Aero. Sci., May, 1956, pp. 507-516. 28 refs. Analysis of developments based on the von Kármán application of the linearized theory to axially symmetric bodies, the Busemann introduction of the concept of a conical flow, the von Kármán general theory of the drag of slender axially symmetric bodies, and the similarity theory for the linearized equation of motion. Includes a study of the basic relations involved. Source superposition methods include: Puckett's use of a planar distribution of sources to solve several fundamental problems of three-dimensional wings, to check the two-dimensional theory, and to calculate the symmetric conical distributions corresponding to triangular wedges, with application of the results to compute lift and drag characteristics of several families of delta wings; Evvard's method to solve for more complex shapes with Ward's modifications; and the extension by Li and Stewart of Evvard's steady state solution to the rectangular wing. Conical flow methods include: Stewart's modification of the Busemann method applying conformal transformations, with an approach in terms of the velocity components, and the integrational procedure to determine drag due to lift of subsonic leading edges.

A FLAT WING WITH SHARP EDGES IN A SUPERSONIC STREAM. A.E. Donov. (Izvestiia Akademii Nauk, USSR, 1939.) US, NACA TM1394, Mar., 1956. 48 pp. Translation. Development of an approximate solution of the problem of a two-dimensional steady supersonic stream of ideal gas, neglecting the heat conduction, around a thin wing at small angles of attack as related to Ackeret, Prandtl, and Busemann results based on the potential supersonic theory and taking into account the vortex formation due to the change of entropy along the shock wave receding from the leading edge of the wing. Includes a determination of the law of pressure distribution along the wing, the lifting force, and the head resistance.

AEROELASTICITY

AEROELASTIC PROBLEMS OF LOW ASPECT RATIO WINGS. I - STRUCTURAL ANALYSIS. G E.A. Thomann. II - AERODYNAMIC FORCES O AN ELASTIC WING IN SUPERSONIC FLOW. App dix - CONTROL SURFACE SPANWISE LOADING FORMULAE. F.A. Woodward. Aircraft Eng., Feb., Mar., 1956, pp. 36-42, 77-81. 10 refs. D velopment of methods to calculate the influence co ficients in multispar wings of any plan form, taki into account shear deflection, chordwise bending and taper and the aerodynamic forces acting on a elastic supersonic wing having arbitrary swept straight leading edges and a supersonic trailing edge. Includes determination of internal forces e pressed as functions of the displacements at the nodes by means of stiffness coefficients; equation of equilibrium; and loads presented in matrix form in terms of the geometrical incidence effective at given wing structural stations. Results in cate: that the sweep of the hinge line and its relation to the wing Mach lines and leading edges are the main parameters; and that by a proper combin tion of the loads acting on symmetrically opposed stations on each side of the wing, the symmetric or anti-symmetric aerodynamic matrix can be for ed, corresponding to pitching and plunging, or ro ing motions of the wing respectively.

INVESTIGATION OF THE OSCILLATING ELLI TIC LIFTING SURFACE IN INCOMPRESSIBLE FLOW. H.G. Kuessner. Max-Planck-Inst. für Strömungsforschung, OSR TR 56-4, 1955. 49 pp. 26 refs. Study to obtain solutions of aerodynamic properties of an elliptic plate oscillating harmoni

cally in steady, incompressible, nonviscous flow for flapping, pitching, rolling, and antisymmetric twisting, and to determine the applicability of these solutions for the development of mathematical tables to be used in conjuction with simple formulae at all values of the aspect ratio from zero to infinity. Method involves doubly periodic solutions of Laplace equations in ellipsoidal coordinates which are the products of the Lamé polynomials represented by Weierstrassian and Jacobian functions. The Lamé polynomials are used to define the ellipsoidal surface harmonics and to calculate their orthogonality coefficients used in the determination of the zero-dynamic derivatives for the elliptic airfoil.

MEASUREMENT OF THE DERIVATIVE z_w FOR OSCILLATING WINGS IN CASCADE. R. D. Milne and F.G. Willox. Coll. of Aeronautics, Cranfield, Rep. 93, 1955. 20 pp. Results of tests on rigid rectangular wings of various aspect ratios oscillating with simple harmonic motion between parallel plates, applicable to airfoils in cascade when the adjacent blades oscillate in antiphase, indicate: a strong Reynolds Number effect on the values of z_w increasing with the decrease in gap-chord ratio, which can be eliminated by fixing a large enough transition wire to the airfoil near the leading edge of both the airfoils and side plates, diminishing the dependence of z_w on the frequency parameter.

A METHOD FOR THE DETERMINATION OF THE DAMPING-IN-PITCH OF SEMI-SPAN MODELS IN HIGH-SPEED WIND-TUNNELS, AND SOME RESULTS FOR A TRIANGULAR WING. Kazimierz Orlik-Rückemann and C.O. Olsson. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 62, Jan., 1956. 26 pp. Development using a model mounted elastically by means of a torsion bar with cruciform section, with the initial oscillation amplitude built up electromagnetically, after which the disconnection of the energy sources results in free oscillation automatically evaluated on a Dampometer. Results indicate a rapid fall of the damping-in-pitch in the transonic range; an agreement with low-speed and transonic theories and experiments on complete models; a considerable deviation when compared to supersonic theory; and an increase of the damping-in-pitch derivative at increasing subsonic speeds reaching a maximum at M = 0.95 - 0.98 and a slight decrease of the damping derivative at increasing speeds in the higher supersonic range.

OSCILLATORY AERODYNAMIC LOADS ON LOW-ASPECT-RATIO WINGS IN SUBSONIC FLOW. I - METHODS OF CALCULATION AND COMPARISON WITH MEASURED LOADS. Appendix A - INTEGRALS FOR PRESSURE-DOWNWASH RELATION. Appendix B - NUMERICAL TABULATIONS OF CERTAIN INTEGRALS. Appendix C - REPRESENTATION OF THE PRESSURE DISTRIBUTION AND ITS DERIVATIVES, IN TERMS OF ITS POINT VALUES. Appendix D - NUMERICAL EVALUATION OF GENERALIZED FORCES. Appendix E - SOLUTION OF THE PRESSURE-DOWNWASH EQUATION ON A DIGITAL COMPUTER. Appendix F - LITERAL EXPRESSIONS FOR GENERALIZED FORCES OBTAINED FROM LOW-ASPECT-RATIO THEORY. Pao-Tan Hsu, J.R. Martuccelli, and Holt Ashley. MIT ASRL TR 52-4, Dec. 1, 1955. 94 pp. 13 refs. Further organization and systematization of the Voss-Zartarian-Hsu pressure-downwash kernel-function method to calculate the distribution, lift, and moment on a square wing subjected to translation and pitching oscillations in a low-speed airstream. Results compare favorably with the Laidlaw wind-tunnel measurements. Includes compilation of flutter equations using the assumed mode approach for a 60°-delta wing with cantilever support at the root, with solutions developed on the basis of: 1) the generalized aerodynamic forces; and 2) the Voss-Hassig low-aspect-ratio theory and modified by the Laidlaw empirical correction factor.

PRELIMINARY STUDY OF SOME FACTORS WHICH AFFECT THE STALL-FLUTTER CHARACTERISTICS OF THIN WINGS. A.G. Rainey. US, NACA TN 3622, Mar., 1956. 33 pp. 11 refs. Results of an exploratory, analytical and experimental study, taking into account Mach and Reynolds Numbers, density, aspect ratio, sweepback, structural damping, location of torsion nodal line, and concentrated tip weights indicate the effect of the compressibility, dependent on the aspect ratio, on the stall-flutter characteristics of thin wings and the importance of the inertia effects of concentrated tip weights; includes an approximate analysis to estimate the stall-flutter characteristics of particular wing-weight configuration.

THE THEORETICAL DETERMINATION OF NORMAL MODES AND FREQUENCIES OF VIBRATION. I.T. Minhinnick. Gt. Brit., RAE Rep. Struc.197, Jan., 1956. 47 pp. 96 refs. Analysis of various methods evaluated in terms of accuracy and the amount of work entailed, with a numerical example to illustrate the comparison. Includes calculation of normal vibration modes of wings, fuselage, and tail units separately, based on the fundamental differential equation, the integral equation incorporating flexibility coefficients, and the Rayleigh Lagrangian equation. The displacement of the system having an infinite number of degrees of freedom is specified at a number of finite points or expressed as a linear combination of known functions, neglecting the effect of shear deflection, shear lag and rotary inertia on the flexural vibrations, and of warping of sections in torsion. Methods described include: the Holzer-Myklestad step-by-step; the Stodola, using iterative integration for solving the differential equations; the solution of integral equations by numerical integration and collocation; the Morris discrete mass method; the Lagrangian or Rayleigh-Ritz; the complementary energy; and the collocation with assumed modes. Results: for the case of a sweptback wing the locus of flexural centers may be straight for most of the span, curved near the wing root and meeting the centerline at right angles assuming a parabolic shape for the deflection of the curved part of the line of flexural centers; for the

case of wings of small aspect ratio the motion is described by the displacement of points over the whole wing area if the flexibility coefficients are known at various points over the surface and if the distortion of chordwise sections is not sufficiently small; displacement functions for wings of the general type for use in the collocation or complementary energy methods can be obtained by a generalization of the Rauscher method; and calculations of the frequencies and modes of the wings encastré at the root and of the fuselage-tail combination encastré at its junction with the wing separately in order to obtain data for a complete aircraft.

THE UNSTEADY AERODYNAMIC FORCES ON DEFORMING, LOW ASPECT RATIO WINGS AND SLENDER WING-BODY COMBINATIONS. Appendix I - THE CROPPED DELTA - DEFINITIONS AND GEOMETRICAL PROPERTIES. Appendix II - EQUIVALENT CONSTANT DERIVATIVES - DEFINITIONS. Appendix III - RESULTS OF A CALCULATION USING UNCOUPLED MODES. Appendix IV - "RIGID" FORCE COEFFICIENTS FOR A SLENDER BODY OF REVOLUTION WITH CONICAL NOSE. Appendix V - "RIGID" FORCE COEFFICIENTS FOR TRIANGULAR WING ON CYLINDRICAL BODY. Appendix VI - "RIGID" FORCE COEFFICIENTS FOR A SLENDER WING-BODY COMBINATION. R.D. Milne. Coll. of Aeronautics, Cranfield, Rep. 94, 1955. 45 pp. 21 refs. Development of a method, based on the slender body theory, to determine the unsteady aerodynamic forces. Includes: calculations based on the simplification of the method; practical application to subsonic and supersonic speeds subject to certain restrictions on aspect ratio, Mach Number, frequency parameter, and slenderness, and dependent on an approximate satisfaction of the Kutta-Joukowski condition.

THE THEORY OF TORSIONAL VIBRATIONS OF A FOUR-BOOM THIN-WALLED CYLINDER OF RECTANGULAR CROSS-SECTION. Appendix I - EFFECT OF BOOM INERTIA IN AXIAL VIBRATION. Appendix II - INCREASE IN STIFFNESS NEAR THE ROOT DUE TO BUILDING-IN. E.H. Mansfield. Gt. Brit., ARC R&M 2867, 1955. 16 pp. BIS, New York. $1.25. Derivation of: a differential equation of motion based on the assumption that the ribs maintain the section shape without resisting any warping out of their plane, and that the walls of the cylinder are effective only in shear; and frequency equations for a length of cylinder, free at both ends and prevented from rotating at the mid-section. Includes a method to estimate the torsional frequencies of a cylinder with nonuniform characteristics. Results indicate that: the complete behavior of the cylinder may be described by the two dimensionless parameters α and β; the simple Batho stiffness is strictly correct only when cross-sections of the cylinder do not tend to warp under torsion; to prevent underestimation of torsional frequencies warping constraints must be taken into account; with warping, there is a difference between the frequencies in the symmetrical and anti-symmetrical torsional vibrations; the frequency of fundamental anti-symmetrical mode is practically that given by the simple Batho theory, with that of the fundamental symmetrical mode up to 20 per cent higher, estimating the increase fairly accurately by assuming a reduced length for the cylinder to represent local stiffening at the root; the frequencies in the symmetrical and anti-symmetrical modes approach each other as the order of the mode increases; and the modes of rotation of a section about x-axis are little affected by warping constraints.

RESULTS OF A FLIGHT INVESTIGATION ON CLEAR AIR TURBULENCE AT LOW ALTITUDE USING A METEOR MK. 7 AIRCRAFT. R.M. Allan. Gt. Brit., RAE TN Aero. 2390, Sept., 1955. 16 pp. Data include distribution of positive and negative gusts, the effect of meteorological conditions on the severity of turbulence, and gust gradient distances.

THEORETICAL STUDY OF THE LATERAL FREQUENCY RESPONSE TO GUSTS OF A FIGHTER AIRPLANE, BOTH WITH CONTROLS FIXED AND WITH SEVERAL TYPES OF AUTOPILOTS. Appendix - CALCULATION OF FREQUENCY RESPONSE OF AIRPLANE-AUTOPILOT COMBINATIONS BY TRANSFER-FUNCTION METHOD. J.J. Adams and C.W. Mathews. US, NACA TN 3603, Mar., 1956. 46 pp. Investigation to determine the frequency response and the power spectral density of the motion to side and rolling gusts at Mach 0.7 and altitude of 30,000 ft. Results indicate: that the response to gust inputs for the airplane with controls fixed shows a large resonance associated with the Dutch roll made of the aircraft; that in combination with various autopilots the resonance is reduced by the addition of yaw damping; that the addition of autopilot components to supply heading and roll stability provides good regulation of yaw and roll responses to gusts; that autopilots controlling side force to low values and providing good course response to command signals results in large roll response to side gusts.

AIRPORTS

Traffic Control

SUMMARY OF JOINT FIL-TDEC SIMULATION ACTIVITIES IN AIR TRAFFIC CONTROL. Appendix A - COMPARATIVE RESULTS AND DISCUSSION OF SOME TERMINAL AREA STUDIES. Appendix B - ENROUTE QUANTITATIVE MEASUREMENT PROGRAM. S.M. Berkowitz, E.L. Fritz, R.S. Grubmeyer, and R.S. Miller. Franklin Inst. Labs. FR F-2384, Aug., 1955. 120 pp. 11 refs. Results of the investigation program for the evaluation of operational concepts of preliminary and finalized designs of equipments and technique, and for the development of new and improved means of simulation. Includes: analytical, graphical, and dynamic techniques and basic requirements for safe and efficient systems of terminal area traffic control in terms of high density traffic requirements, congestion and delays, including the problems of

altitude distribution, altitude changes and intersections; problems associated with the introduction of very slow aircraft types, helicopters, and jets; criteria for the design and evaluation of displays, coordinating equipment, communications, radar and nonradar control, their interactions and compatibility enroute; realistic mathematical analogs to describe and permit simple and inexpensive first-approximation evaluations of departures, enroute and terminal area arrivals; development of an electronic target generator for use in TDEC's electro-mechanical dynamic simulator, and a synchro-target repeater-type of simulator; establishment of functional requirements and characteristics for a new, all-purpose, universal simulator.

EDUCATION AND TRAINING

HELICOPTER FLIGHT TRAINER. Luis de Florez and E.K. Smith. (IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 626.) Aero. Eng. Rev., May, 1956, pp. 114-125. Analysis of the basic experimental and theoretical concepts applied to the development of the trainer design in terms of the problems of excessive requirement for hangar or ramp space, lack of flexibility for future adaptation to instrument training and broader ranges of flight, limited operating flexibility, and high construction cost to reproduce helicopter dynamics.

ELECTRONICS

Cooling

COOLING PROCEDURES NECESSARY TO AVIONIC RELIABILITY. J.P. Welsh. (IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 627.) Aero. Eng. Rev., May, 1956, pp. 110-113. Recommendations for an overall systems approach in the design of electronic components to control and direct waste heat away from all sources in the aircraft through specific paths to the ultimate sink, taking into account the ambient temperature and pre-installation and operational thermal environments. Includes cooling requirements specifications as related to the airframe design; and a discussion on the future application of thermoelectric cooling using a thermocouple to convert heat into electric energy.

Oscillographs

THE DTMB FOUR-CHANNEL OSCILLOGRAPH TYPE 214; DESIGN DETAILS AND OPERATING INSTRUCTIONS C.W. Hoffman. US, Navy Dept., David W. Taylor Model Basin, Rep. 965. Oct., 1955. 65 pp. Includes a description of two types of plug-in preamplifiers direct coupled and chopper stabilized with an overall sensitivity of 10 mv peak-to-peak per in., and resistance-capacitance coupled and used with balanced and unbalanced inputs. Results indicate that two four-channel units may be stacked for the simultaneous recording of eight signals on a drum camera using 70 mm. film; that single, driven, and recurrent sweep circuits permit the use of conventional methods of oscillograph recording; and that a precision timing circuit can be used to supply accurate time-interval marks on still or moving film records.

Radar

HIGH-SPEED PRECISION RADAR-DATA RECORDER. G.H. Wayne and I.L. Resnick. Electronics Corp. Amer., AFMTC TN-56-13, Mar. 1, 1956. 25 pp. Development of a device to operate with a NIKE missile-tracking radar to record azimuth, elevation, range, and target-identification data on six-channel, 27 line tape. Positional data are extracted directly from the respective shafts of the tracking radar by special shaft-digitization encoders comprizing a flashing-light source, a coded disk mounted on each shaft, and a photocell for each binary circuit involved; azimuth and elevation data are produced by angular travel of the radar as it tracks the target and encoded at discrete time intervals as 16-digit cyclical-binary words on two banks of magnetic cores, and then, guided by a master clock, fed serially to a three-core buffer storage.

EQUIPMENT

Electric

THE IMPACT OF ELECTRONIC EQUIPMENT ON ELECTRIC GENERATOR DESIGN AND AIRCRAFT POWER PLANTS. Henry Rempt and M.J. Cronin. (IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 628.) Aero. Eng. Rev., May, 1956, pp. 87-93, 125. Analysis of the specific fuel and power requirements of accessories and the most efficient sources of supply in terms of compactness, economy, and the overall aircraft efficiency; includes a discussion on choice of voltage and frequency, the effects of electrical generating system on piston engines, turboprops, and turbojet engines, and an evaluation of the four main types of accessory drives.

FLIGHT TESTING

FREE FLIGHT TECHNIQUES FOR HIGH SPEED AERODYNAMIC RESEARCH. Appendix I - DETAILS OF THE ANALYSIS PROCEDURES USED TO OBTAIN ROLL DERIVATIVES. Appendix II - DETAILS OF THE ANALYSIS PROCEDURES USED TO OBTAIN PITCH DERIVATIVES. Appendix III - A NOTE ON ACCURACY. J.A. Hamilton and P.A. Hufton. J. RAeS, Mar., 1956, pp. 151-177; Discussion, pp. 177-185. 11 refs. General survey and evaluation to determine validity for continued use, in terms of early and future developments, recording methods, and models, with comparison to wind tunnel techniques. Results indicate that the continued use of free flight testing techniques is valid: to obtain the limited amount of information necessary to provide a correct frame of reference for the tunnel results; to check on those problems where the attainment of high Reynolds Number is an es-

sential for correct flow representation; and to act as extension to the tunnel when results are required at Mach Numbers beyond tunnel limits.

FLIGHT TESTING TECHNIQUES & ANALYSIS: OPTIMUM CLIMB THEORY AND TECHNIQUES OF DETERMINING CLIMB SCHEDULES FROM FLIGHT TEST. Appendix I - EQUATIONS AND PROCEDURE FOR COMPUTING CLIMB TECHNIQUES ACCORDING TO "EXACT" EQUATIONS. Appendix II - LEVEL FLIGHT ACCELERATION. Appendix III - ANALYSIS OF AIRSPEED INDICATOR TIME HISTORY FROM LEVEL ACCELERATION. K.J. Lush. USAF FTC TN-56-13, Feb., 1956. 47 pp. Review of the developments to provide an easy reference and a starting point for extension to the supersonic airplane. Includes: definition of climb schedules to reach a given height in the shortest distance from take-off; for minimum time, minimum fuel used, or maximum range; and for interception at maximum distance requiring a substantially higher speed and the use of a rate of climb indicator connected to the total pressure source, as a recorder, to provide an accurate "quick-look" answer.

FUELS AND LUBRICANTS

INTERFERENCE EFFECTS DURING BURNING IN AIR FOR STATIONARY n-HEPTANE ETHYL ALCOHOL, AND METHYL ALCOHOL DROPLETS. J.F. Rex, A.E. Fuhs, and S.S. Penner. Jet Propulsion, Mar., 1956, pp. 179-187. OOR-supported experimental investigation to determine the evaporation constant and flame shapes of two and five closely spaced droplets. Results indicate a linear decrease of the square of droplet diameter with time for fixed spacing between droplet centers; the invariancy of the evaporation constant with time for two droplets burning in close proximity and for the center one of a five-droplet array and its dependence on the droplet arrangement.

ZUR HYDRODYNAMISCHEN THEORIE DER SCHMIERMITTELREIBUNG. W. Philipzik. ZAMM, Jan.-Feb., 1956, pp. 51-60. 10 refs. In German. Application of the Reynolds theory to semi-enclosed cylindrical bearings of finite width for constant or variable viscosities of the lubricant. Solution of partial differential equations with constant boundary values by means of the method of differences, and of systems of equations by means of the Gauss-Southwell relaxation method. Includes: analysis of the axial pressure distribution; and a minimum theorem for bearing friction.

SOLUTION OF THERMOCHEMICAL PROPELLANT CALCULATIONS ON A HIGH-SPEED DIGITAL COMPUTER. A.J. Donegan and M. Farber. Jet Propulsion, Mar., 1956, pp. 164-171. Army-sponsored development at CIT of a code operating on the basis of a three-cycle iterative scheme to determine the chamber conditions or the combustion gas composition, with a computation of the performance parameters based on an adiabatic isentropic expansion of the combustion gases from the rocket chamber through the nozzle attaining an equilibrium flame temperature characteristic of the product formed during the burning process.

ICE FORMATION AND PREVENTION

ON THE MOTION OF SMALL PARTICLES IN A POTENTIAL FIELD OF FLOW. Abraham Robinson. Commun. on Pure & Appl. Math., Feb., 1956, pp. 69-84. Analysis of the fluid particle phenomena pertinent to aircraft icing problems by assuming Stokes' law and by considering the virtual field of flow produced by a continuous distribution of small particles governed by the specified equations of motion. General properties are derived for the field of flow including effects of gravity or particle flow, and reduced to a formula for the total mass of particles deposited on a slender obstacle or plane wall.

REFERENCE PRESSURE PROBES FOR AN ORIFICE-TYPE ICING DETECTOR. Appendix A - PRESSURES IN AN ICING DETECTOR SYSTEM. Appendix B - CHARACTERISTICS OF A PRESSURE REFERENCE PROBE CONFIGURATION INSENSITIVE TO YAW. D. Fraser and D.C. Baxter. Canada, NAE Note 12 (LR-129), 1956. 29 pp. Results of tests indicate that: a flush-type static vent may not provide a satisfactory reference pressure for an orifice-type icing detector used in an engine intake duct; if continuously anti-iced and protected from overheating, a production icing detector probe with the proportion of front to rear holes adjusted would provide a suitable reference pressure over a wide range of angles of yaw relative to the longitudinal axis of the probes; and a production icing detector probe with enlarged holes mounted adjacent to the normal detector probe de-iced simultaneously would also provide a suitable reference pressure.

INSTRUMENTS

Flight Instruments

INTEGRATED FLIGHT EQUIPMENT SYSTEM WITH A PRIMARY EMPHASIS ON INSTRUMENTATION AND CONTROLS. C.F. Fragola and M.A. Sant Angelo. (IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 623.) Aero. Eng. Rev., May, 1956, pp. 62-69. Analysis of the concepts of redundancy and duplication emphasizing the optimum use of monitor and standby instrumentation as related to human requirements of aircraft control design in terms of time delays limiting the maximum speed of the control loop response and taking into account environmental disturbances.

Flow Measuring Devices

HOT-WIRE ANEMOMETER FOR MEASUREMENTS IN UNSTEADY FLOW. O. Wehrmann and R. Wille. Tech. U., Berlin-Charlottenburg, Hermann Föttinger-Inst. Strömungstech. TN 56-26, n.d. OSR-sponsored investigation, with design specifications of the anemometer using carrier-frequency amplification and automatic control of the con-

stant wire temperature applied in free-jet research to determine the mean velocity distribution, taking into account King and Dryden-Kuethe formulas.

Pressure Measuring Devices

PRESSURE-MEASURING INSTRUMENTATION FOR COMBUSTION STABILITY STUDIES. Leon Green, Jr. Appendix - INSTRUMENT LINE TRANSMISSION CHARACTERISTICS. Seba Eldridge, Jr. Aerojet-Gen., TN-14 (OSR-TN-55-474), Dec., 1955. 40 pp. 14 refs. Experimental investigation using two parallel pressure-measuring systems: 1) of relatively low frequency response to record mean chamber pressure and 2) of high frequency response to detect fluctuations around the mean value using a variable-capacitance pressure transducer. Includes recommendations for future application of the Li-Liu strain-gage pressure pickup; low-noise-level, frequency-modulated tape recorders; and the shock-tube technique for pressure-gage calibration.

Stress and Strain Measuring Devices

AN ELECTRONIC APPARATUS FOR ACCURATE MEASUREMENT OF PERIODIC STRAINS. G.V.A. Gustafsson and C.O. Olsson. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 63, 1956. 13 pp. Design and operational characteristics of the strain and load measuring device in terms of greater accuracy in fatigue tests used as a calibrator to determine the actual load values, applied to compare different fatigue machines by means of an uncalibrated load cell and to calculate their frequency sensitivity; and to measure the strains in the specimens at the same time as the loads applied through a calibrated load cell connected in series with the specimen.

MATHEMATICS

FEHLERABSCHÄTZUNG FÜR DIE ZWEITE RANDWERTAUFGABE DER EBENEN POTENTIALTHEORIE. G. Bertram. ZAMM, Jan.-Feb., 1956, pp. 1-35. In German. Development of a method for the estimation of error for the second boundary value problem of the plane potential theory, obtained from the Green representation of solutions for the circle, using conformal mapping. The method is also used for the estimation of the maximum amount of error of a harmonic approximation.

MISSILES

SOME PRINCIPLES OF MISSILE GUIDANCE. R. C. Gibson. (IAS 24th Annual Meeting, New York, Jan. 23-26, 1956, Preprint 634.) Aero. Eng. Rev., May, 1956, pp. 70-75. Development of systems applicable to surface-to-air, air-to-air, and surface-to-surface missiles, featuring Ground-Based Command Guidance for attack on moving targets for surface-to-air and air-to-air operations considered in terms of proportional navigation with the missile-turning rate proportional to the rate of change of the line-of-sight; Beam-Riding Guidance for surface-to-air missiles; and Loran's Hyperbolic Guidance for surface-to-surface missiles, as a method based on celestial or inertial navigation and man-made aids.

SULLE PRESTAZIONI E SULLE CARATTERISTICHE DEL MISSILE. Corrado Casci. L'Aerotecnica, Dec., 1955, pp. 291-297. In Italian. Results of an investigation of missile performance indicating the influence of drag which can be neglected at 60 km., but at 10--39 km. requires the increase of the propellant mass flow in order to attain supersonic speeds; and the use of diagrams as function of the propellant mass flow and diameter of the missile body to obtain the best operational conditions for air-to-air and ground-to-air missiles.

PHYSICS

THE BEHAVIOR OF NONLINEAR SYSTEMS. F.H. Clauser. J. Aero. Sci., May, 1956, pp. 409-432. 100 refs. Review of progress in understanding the behavior of nonlinear systems, with a tentative presentation of resulting concepts in terms of application to general problems. Includes: classification of systems into linear, nonlinear, kinematic, and dynamic; properties of a system; independent variables; behavior of systems with single and several independent variables; the effects of nonlinearity covering resonance, hysteresis, waves, feedback, boundary layers, turbulence, shock waves, and weatherfronts.

POWER PLANTS

Jet and Turbine

IL TURBOGETTO CON POSTBRUCIATORE, PROPULSORE PER VELOCITÀ SUPERSONICHE - LIMITI PROBABILI PER BARRIERA TERMICA INTERNA ED ESTERNA. Gaspare Santangelo. L'Aerotecnica, Dec., 1955, pp. 307-318. In Italian. Investigation of basic phases of turbojet engine operation in the subsonic range. Includes: study of the afterburner as a means for temporarily increasing the thrust; analysis of possible limitations due to internal and external thermal phenomena; and evaluation of the air mass flow, with a derivation of formulas for the performance of the propulsive system applied to a simple turbojet engine with and without afterburner.

EXPERIMENTELLE ERMITTLUNG VON MESSGRÖSSENFELDERN AN HOCHTOURIGEN TURBINENLÄUFERN. Karl Leist. ZFW, Mar.-Apr., 1956, pp. 128-140. In German. Investigation of the structure of local distribution of various parameters using newly improved techniques, based on results of turbine rotor tests for the determination of such values as efficiency, r.p.m., and torque.

Rocket

TWO METHODS FOR MEASURING IGNITION DELAYS OF SELF-IGNITING ROCKET PROPELLANT COMBINATIONS. D.J. Ladanyi and R.O. Miller. Jet Propulsion, Mar., 1956, pp. 157-163. Development of measuring techniques at various conditions of simulated altitude using a modified-cup apparatus to obtain rapid propellant mixing by crushing a fuel-filled glass ampule under the surface of the oxidant and a transparent-sided rocket engine of approximately 50 lb. thrust, with data on combustion-chamber, propellant-injection, and al-

titude-tank pressures and on fuel, oxidant, injector head, constant-temperature bath, nozzle plate, and ambient air temperatures. Results indicate a rapid increase in ignition delays with propellant viscosities under 20 centistokes for the modified open-cup apparatus and no significant change in the small-scale engine under 200 centistokes.

ROTATING WING AIRCRAFT

ON THE USE OF A TENSOR TRANSFORMATION TO DESCRIBE THE ROTATION OF A RIGID BODY; WITH APPLICATIONS TO A WING OF VARIABLE SWEEP AND A RETRACTABLE UNDERCARRIAGE. E.H. Bateman. Gt. Brit., RAE Rep. Struc. 190, Oct., 1955. 20 pp. Derivation of a general solution based on a tensor transformation to determine the position of a rigid body after rotation of a known axis, and conversely to find the direction of the axis when a body is transposed from one position to another, with a derivation of expressions for the angles of sweep, incidence, and dihedral when a wing of variable sweep is rotated about any fixed axis. Includes a method to determine the axis of rotation of an undercarriage based on an engineering layout definition in plan and elevation of the extended and retracted orientations.

SOME ASPECTS OF NIGHT AND INSTRUMENT FLYING ON SINGLE ROTOR HELICOPTERS. D.A. Wilkinson. Gt. Brit., AAEE Rep. Res/291, 1956. 29 pp. Results of investigations including ground lighting equipment and patterns, approach path angles, entry into restricted sites, use of parachute flares during emergency landing, and cockpit lighting. Includes an evaluation of the Thorne lighting installation on Sycamore Mk. 3 pilot panel and an experimental analysis of the effects of failure of single or groups of instruments. Results further indicate that: the changes in fuselage attitude recorded by the artificial horizon are unreliable as indications of flight path or speed as the change from climbing to autorotative flight is normally accompanied by a nose-up fuselage change and a lag exists between movements of the cyclic control and the resulting changes in fuselage altitude, particularly in the pitching plane; two-handed coordination is required since the collective pitch and throttle, as well as the cyclic control, are used constantly; close control of rotor speed requires concentration on the tachometer as an additional primary instrument; control of heading requires constant attention to the slip and direction or turn indicators due to the poor directional stability and corresponding changes in rudder pedal position for the changes of power at constant rotor speed; and a large proportion of the available speed range lies below the speed for minimum power where a progressive deterioration of the airspeed reference and of general handling qualities as zero airspeed is approached.

STRUCTURES

FATIGUE ASPECTS OF STRUCTURAL DESIGN. W.A.P. Fisher. J. RAeS, Mar., 1956, pp. 198-202. Evaluation of the "fail safe" principle applied to the component design using generalized endurance curves for wing tension booms with special emphasis on spar joints and spar boom with holes. Includes: curves for the correction of mean stress, the spar boom with unloaded flange holes, choice of material, comparison between spar joint and flange hole curves, choice of ultimate design stress, and statistical treatment for scatter.

INELASTIC BUCKLING - FROM A DESIGNER'S VIEWPOINT. E.E. Sechler. J. Aero. Sci., May 1956, pp. 500-506. 41 refs. Analysis of buckling in the plastic range in order to determine methods of calculating stresses and deformations suitable for design purposes. Includes solutions for the general case of inelastic buckling with and without creep as applied to specific examples: stable cross section columns; plates under compression; plates under shear; thin-walled columns; and cylinders.

STAND DER FESTIGKEITSFORSCHUNG IM FLUGZEUGBAU UND AUF ANDEREN GEBIETEN DES LEICHTBAUES. Hans Ebner. ZFW, Mar.-Apr., 1956, pp. 108-121. 42 refs. In German. Review of investigations of the problem of structural strength, including: methods to study the state of stress in stiffened sheet metals; results of research on thermal stress in structures as related to high speed aircraft and missile requirements; and a summary of problems related to the stability of light construction elements such as skin covered bars, cylindric shells, and stiffened spherical shells.

Bars and Rods

THE PROPAGATION OF DYNAMIC STRESSES IN VISCO-ELASTIC RODS. D.S. Berry and S.C. Hunter. J. Mech. & Phys. Solids, Feb., 1956, pp. 72-95. Analysis of the propagation of mechanical waves in thin rods under the assumptions that: the strains are infinitesimal, and that the variations in the cross-section of the rod during the motion, and the effect of the inertia of the associated lateral motion on the longitudinal motion can be neglected; that the material of the rod satisfies a general linear relation based on the Boltzmann principle of superposition; and that there are no operative body forces. Includes application of the Laplace transform to convert equations of motion and the stress-strain relation, and the equation of relating displacement to strain, into a system of ordinary differential equations.

Connections

CORRELATED FATIGUE DATA FOR AIRCRAFT STRUCTURAL JOINTS. Appendix - DERIVATION

OF AVERAGE JOINT CURVE. R.B. Heywood. Gt. Brit., ARC CP 227, 1955. 16 pp. BIS, New York. $0.50. Correlation of results plotted in the form of S - Log N curves of tests on extruded, rolled or forged aluminum alloy joints and spar booms in which a constant fatigue loading cycle in axial tension is used in order to obtain conditions representative of those on the tension side of a wing. Results further indicate that: the fatigue strength of typical aluminum alloy structural joints depends principally on the detailed method of design; for failure in given cycles, the joints of the best design, which can sustain an alternating stress of about four times the magnitude of that for joints of the worst design, can only sustain one-fourth that of polished laboratory specimens; the use of interference fit bolts or rivets, of high clamping action by the bolt, and of preloading can improve fatigue strength; and the design stress for the 50 ft. per sec. gust case should be of the order of 35,000 psi, assuming joint average design, to yield an aircraft life of 30,000 flying hours.

Cylinders and Shells

DYNAMIC LOADING OF RIGID-PLASTIC CYLINDRICAL SHELLS. G. Eason and R.T. Shield. J. Mech. & Phys. Solids, Feb., 1956, pp. 53-71. Analysis of the behavior of shells subjected to impulsive loading, by a ring of concentrated force and a band of uniform pressure, assumed to be greater than the statical collapse values, with numerical results for rectangular and triangular pulse shapes for the ring of force and for rectangular pulse shape for the band of uniform pressure. Includes a determination of the steady-state motion produced by a constant load greater than the statical value moving along the shell with constant velocity for the cases of a ring of force and a band of uniform pressure.

Elasticity and Plasticity

THE ELASTIC-PLASTIC THEORY OF COMPRESSION MEMBERS. M.R. Horne. J. Mech. & Phys. Solids, Feb., 1956, pp. 104-120. Derivation of expressions for the curvature of an initially straight prismatic member of rectangular cross section subjected to any combination of axial load and bending moment about a principal axis, under the assumption that the material is subject to elasto-plastic behavior, with a finite drop of stress at yield. Includes a method for the determination of the collapse load of a member subjected to terminal moments combined with any degree of elastic end restraint.

ZUR FESTIGKEITSRECHNUNG BEI GEMISCHT ELASTISCH - PLASTISCHER VERFORMUNG. Alex Troost. ZFW, Mar.-Apr., 1956, pp. 122-128. In German. Development of a method for the evaluation of strain limits in the elasto-plastic range indicating the general relations between the deformation limits under homogeneous and nonhomogeneous stresses for static and dynamic loads. Includes an evaluation of bend-strain limits and the notch sensitivity, with a comparison to test results.

Plates

OBLIQUE BENDING OF A RECTANGULAR PLATE. Carlo Riparbelli. Cornell U. Grad. Sch. Aero. Eng., OSR TN-55-147, 1955. 38 pp. Analysis applied to plate-like wings of small aspect ratio of the deformation of a thin, free-edged rectangular plate in equilibrium under the action of opposite moments forming a given angle with the plate axis in terms of the lines of maximum curvature assumed as intrinsic coordinates. Results indicate that the rotation of the sections occurs about axes inclined at an angle equal to one half of the angle formed by the moment vector with the normal to the plate axis; that at the edges the lines of maximum curvature, defined analytically, form an angle with the normal to the plate axis equal to one fourth of the angle formed by the moment with the same direction; and that the principal curvature is approximately uniform and the second one is negative and increases in absolute value from the plate middle line towards the edge.

ZUR BERECHNUNG DER BEULWERTE VON LANGS= ODER QUERVERSTEIFTEN RECHTECKIGEN PLATTEN UNTER DRUCKLAST. W. Schnell. ZAMM, Jan.-Feb., 1956, pp. 36-51. 10 refs. In German. Calculation of the critical compressive stresses in plates with longitudinal or transversal reinforcements using sets of matrices. Results indicate that: the boundaries perpendicular to the reinforcements must be hinged; and that for two other boundaries any conditions may be given.

Wings

OPTIMUM STRUCTURAL DESIGN OF WING BOX BEAMS. Appendix I - DERIVATION OF EQUATIONS FOR MAXIMUM COMPRESSIVE STRESS. Appendix II - DERIVATION OF OPTIMUM PANEL PROPORTIONS. Saul Bernstein. Can. Aero. J., Mar., 1956, pp. 91-99. Analysis of such types of compression covers on wing box beams as: skin and Z-section stringers, double skin and corrugation panels, and solid plate multi-web construction, with data derived for the selection of most efficient rib and web spacing and of actual dimensions of the panel. Includes a comparison based on the applied bending moment per in. width of structural chord, the depth of the box beam, and on the minimum skin thickness required for torsional rigidity.

THEORY OF MULTI-SPAR AND MULTI-RIB WING STRUCTURES. Alex. Grzedzielski. AVRO Rep. Gen/1090/336, 1955. 84 pp. 15 refs. Application of redundant distribution of plate bending and torque moment to stress and deflection analysis of low aspect ratio wings, with emphasis on the use of digital computer to obtain solutions, taking into account the effects of wing sweep, taper, lateral contraction, and torsional warping. An approximative moment distribution is assumed to satisfy equilibrium conditions, leaving strains incompatible, connected by several properly chosen self-equilibrated groups of internal loads, their magnitude being de-

termined from the Castigliano theorem by solving a large set of linear equations; displacements are computed by the dummy unit load method.

THERMODYNAMICS

EXTREME GESCHWINDIGKEITEN UND THERMISCHE ZUSTÄNDE BEIM ÜBERSCHALLFLUG. Klaus Oswatitsch. ZFW, Mar.-Apr., 1956, pp. 95-108. In German. Summary of problems related to high speed flow, including the change of high kinetic energy into extreme thermodynamic states with temperatures of several thousand degrees Kelvin. Discussion of: temperatures higher than those of the sun's surface which are produce by the entrance of meteors into the atmosphere with astronomical speed; the problem of heat generation on the surfaces and in the combustion chamber of supersonic fighters; and, for space rockets, astronomical speeds for which fuels of low molecular weight are most suitable.

Combustion

THE FILM COMBUSTION OF LIQUID FUEL. H. W. Emmons. ZAMM, Jan.-Feb., 1956, pp. 60-71. Investigation of the combustion problem assuming that the mass and heat transfer are the controlling variables which remove the chemical reaction zone from droplets larger than 10^{-1} in. to a region where the zone is less sensitive to the effects of the droplet itself. The steady boundary layer motion along a plate with zero pressure, assumed to consist of evaporating fuel, is described by the continuity equation, the equation of motion with the pressure assumed constant, the energy equation, and the equation of conservation of oxygen. Includes a comparison of the theory to experimental data on sphere combustion.

FLAME THEORY AND COMBUSTION TECHNOLOGY. F.E. Marble. J. Aero. Sci., May, 1956, pp. 460-466. 22 refs. Study of combustion processes described by the motion of nonuniform gaseous mixtures in which chemical reaction produces concentration gradients and, consequently, diffusion of chemical species, with a review of equations of aerothermochemistry for the case of small temperature and composition gradients. Includes: determination of mean values for the velocity, density, and temperature of the gas mixture based on the Chapman-Cowling or Hirschfelder, Bird, and Curtiss methods; analysis of the theory of plane laminar flames; and extensions to two-dimensional problems.

NON-STEADY BEHAVIOR OF A SIMPLIFIED MODEL OF SOLID-PROPELLANT BURNING. Appendix - SOLUTION OF HEAT-FLOW EQUATIONS FOR HIGH- AND LOW-FREQUENCY REGIMES. Leon Green, Jr. Aerojet-Gen., TN-15 (OSR-TN-55-475), Nov., 1955. 21 pp. Results of analyses of the non-steady behavior of thermal model, considering that a small time interval is required for completion of the phase change of the propellant from the solid to gaseous state in a thin zone or burning "surface", indicate that: when the simplified transfer coefficient assumed to govern heat flow to the surface fluctuates at high frequencies, the coupling between the heat-transfer fluctuation and the decomposition reaction can cause large amplitude oscillations of the surface temperature and significant deviations in the mean effective burning rate from its nominal steady-state value; and that the predicted dependence of the model behavior upon the propellant and operating condition parameters is in qualitative agreement with the known behavior of actual propellants.

THE THEORY OF FLAME PHENOMENA WITH A CHAIN REACTION. Appendixes A, B - DIMENSIONAL ANALYSIS OF THE FLAME EQUATIONS. D.B. Spalding. Philos. Trans. Royal Soc. (London), Ser. A, Mar. 22, 1956, pp. 1-25. 17 refs. Theoretical analysis of three types of flame: spontaneous ignition, laminar-flame propagation, and the homogeneous steady-flow reaction zone, using the Adams and Stocks hydrazine decomposition scheme. Development of a general method to calculate laminar-flame speeds with reaction schemes of arbitrary complexity. Results: the relation between the volumetric rate of energy conversion and the gas temperature is not unique for the combustion by a chain reaction of a given substance in a prescribed initial state but depends on the type of flame which occurs; theoretical one-dimensional laminar-flame problems can be solved by using equations with reference to a stretching co-ordinate system fixed relative to the gas; the flame speed is independent of the equilibrium radical concentration in the burned gas and the existence of radical-destroying reaction is not necessary to keep the flame speed within finite limits; chain-branching produces flame speeds of approximately one order of magnitude greater than non-branching; the effective activation energy of the complete reaction, including the simplified non-branching reaction, is approximately equal to the mean activation energy of the component reactions; and the von Karman-Penner steady-state assumption may considerably overestimate the radical concentrations and, hence, the flame speed.

Heat Transfer

HEAT TRANSFER IN TURBULENT SHEAR FLOW. W.D. Rannie. J. Aero. Sci., May, 1956, pp. 485-489. 15 refs. Investigation of the problem taking into account the von Kármán analogy of fluid friction and heat transfer and the Taylor extension of the Reynolds analogy dividing the flow into a laminar layer next to the wall and a turbulent region. Includes a method to extend the analysis to higher Prandtl Numbers.

WATER-BORNE AIRCRAFT

COMPARISON OF THE CHARACTERISTICS OF A HYDROFOIL UNDER CAVITATING AND NONCAV-

ITATING OPERATION. T. Yao-tsu Wu and Byrne Perry. CIT Hydrodynamics Lab. Rep. 47-4, Sept., 1955. 32 pp. 17 refs. Investigation based on a two-dimensional theory of fully cavitated and fully wetted hydrofoils in order to determine the hydrodynamic properties of each. Includes: quantitative comparisons to determine the effects of angle of attack, camber, submergence, and speed of the hydrofoil in two regimes; and the effect of air ventilation as applied to the supporting struts.

A FULL-SCALE INVESTIGATION INTO THE HYDRODYNAMIC BEHAVIOUR OF A HIGHLY FAIRED FLYING-BOAT HULL. J.A. Hamilton. Gt. Brit., ARC R&M 2899, 1956. 36 pp. BIS, New York. $2.25. Study of a modified Sunderland with a main-step fairing of 17:1 ratio equipped with ventilating ducts drawing air at atmospheric pressure through ports on the hull side and discharging it through exit vents on the afterbody planing bottom. Results indicate that: a highly faired hull is hydrodynamically satisfactory when a ventilating area equivalent to $0.042\ (\text{beam})^2$ is placed immediately behind the main step line; step line must be kept sharp, but only an angular discontinuity in the vertical plane is necessary; without ventilation, the highly faired hull exhibits severe hydrodynamic instability during take-off and landing, and the resistance is approximately 30 per cent higher than the ventilated hull; and pressure measurements on afterbody indicate that the skipping instability is caused by a region of subatmospheric pressure covering almost the whole afterbody during skipping.

WIND TUNNELS AND RESEARCH FACILITIES

AN AUTOMATIC SELF-BALANCING CAPSULE MANOMETER. G.F. Midwood and R.W. Hayward. Gt. Brit., RAE TN Aero. 2382, 1955. 33 pp. Development of an apparatus to measure the pressure in supersonic wind tunnels covering a range of zero to two atmospheres absolute and calibrated to give an accuracy of 0.01 in. mercury over the range of 0.5 to 60 in. mercury absolute using a remote reading indicator for digital recording. Results indicate that the assembly and alignment of the component parts requires great precision that the spring centers and lines must be initially and remain flat; that the amplifier must be free from drift; and that the manometer is sensitive to drafts and requires a protecting ventilated shield or cover and a "warming-up" period of approximately 30 min.

ELEVATED STAGNATION TEMPERATURE AND STRAIN GAUGE BALANCES IN THE INSTRUMENTATION OF A SUPERSONIC WIND TUNNEL. G.P. Tonkin. (Bristol Aircraft Ltd., Wind-Tunnel Dept. Rep. W.T. 266, Dec., 1955.) 8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20-25, 1956. 62 pp. 11 refs. Development of strain gage ans sting balance design in terms of resistance to prolonged high temperatures, sensitivity, ultimate cement and wire strength, size, expansion, handling, and application. Includes a description of jig and winding, plating of lead-out wires, surface preparation, and bonding cements, pitch, yaw, rolling moment, and drag measurements, interaction, calibration, and manufacturing tolerances.

EVALUATION AND CALIBRATION OF WIRE-STRAIN-GAGE WIND TUNNEL BALANCES UNDER LOAD. R.M. Hansen. (US, NACA, Paper, Jan., 1956.) 8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20-25, 1956. 20 pp. Experimental investigation to determine accuracy, deflections under load, hysteresis and repeatability, gaging and wiring checks, and the balance load proofing using dead-weight and jack and load-cell loading systems.

MACH NUMBER MEASUREMENTS IN HIGH-SPEED WIND TUNNELS. J.A.F. Hill, J.R. Baron, and L.H. Schindel. (MIT NSL TR 145, Jan., 1956.) 8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20-25, 1956, Paper. 121 pp. 81 refs. USAF-Navy-supported analytical development of methods to measure subsonic and supersonic Mach Numbers in terms of calibration of an empty wind tunnel, of local Mach Numbers at points in the flow field around a model, and of simulating free-flight Mach Number in the presence of wall interference under the assumption that the flow is steady and neglecting the time lag and frequency response of the instrumentation. Includes an evaluation of the effects of pressure, density, velocity, temperature, mass flow, and wave geometry on Mach Number; and accuracy requirements and limitations of errors due to departure from the assumed flow conditions.

PROBLEMS INVOLVED IN PRECISION MEASUREMENTS WITH RESISTANCE STRAIN GAGES. K.H. McFarland and John Dimeff. 8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20-25, 1956, Paper. 20 pp. 13 refs. Study of the mechanical, electrical, and environmental effects on strain gage accuracy, taking into account such factors as: electrical resistance heating, environmental temperature changes, thermoelectric effects, leakage due to grounding, hysteresis, and bonding effects. Results: need for longest gage with the highest resistance possible, resistance in gages should be similar, gage temperature characteristics should be corrected after assembly, and gages should not be mounted on hardened surfaces that have been machined or sand blasted.

SPECIAL TYPES OF INTERNAL STRAIN GAGE BALANCES. T.L. Smith. 8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20-25, 1956, Paper. 17 pp. Development of four types of strain-gage balances used for force measurements in the Ballistic Res. Lab. supersonic wind tunnels: a low-interaction three-component balance to measure drag from normal forces; a four-component balance for measuring Magnus forces on spinning models; a dynamic balance for

the measurement of damping in pitch; and a two-component balance for giving front and rear normal force for long slender bodies.

STRAIN GAUGE BALANCES FOR WIND TUNNELS: AN OUTLINE OF PRACTICE IN THE UNITED KINGDOM. J.R. Anderson. (Gt. Brit., RAE TN Aero. 2434, Jan., 1956.) 8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20-25, 1956, Paper. 69 pp. Balance design and fabrication specifications including complete model, rear and internal sting, internal hinge moment, half-model, centre-strip axial force, and other types and covering such factors as materials and stressing, thermal effects and compensation, measuring of rolling moment and axial force, deflections, machining accuracy and finishing, alignment, interactions and nonlinearity, and evaluation and calibration.

THE DEVELOPMENT OF A FLOW VISUALIZATION TECHNIQUE. Appendixes I, II - THE INTENSITY OF LIGHT IN A MOVING IMAGE. Appendix III - SCALING LAWS. E.C. Roberson. Gt. Brit., NGTE Rep. R.181, Nov., 1955. 39 pp. Variant of water analogy, using as markers synthetic resin spheres having suitable optical properties with the particle/fluid density ratio falling within the limits indicated by a mathematical analysis; a rig designed to meet the flow requirements of a wide range of combustion system models, with rubber linings to obviate the turbidity produced by fluid corrosion on metal parts; and a lighting system based on an A. C. 1000 watt mercury vapor lamp and a method to measure quickly and accurately the flow angles and velocities recorded in the resulting photographs. Results indicate that a good representation of flow regimes can be obtained when the density ratio of particle-to-fluid lies in the 0.99 to 1.01 range; that the required properties in good markers are an opacity comparable to that of diluted milk and a specific gravity of 1.00 in spherical particles made of polystyrene or polyethylene; that the particle diameter should be as large as possible compatible with the dimensions of the model and the illuminating flash duration as long as possible; and that the scale of the transparent model should be as large as possible consistent with pump capacity in order to obtain low driving pressures and to use relatively large particles.

CHOKING EFFECTS AND SOME REYNOLDS NUMBER EFFECTS ON THE MACH NUMBER DISTRIBUTION ROUND A TWO-DIMENSIONAL AEROFOIL IN THE RAE 10-ft x 7-ft HIGH-SPEED TUNNEL. D.A. Clarke and H.E. Gamble. Gt. Brit., ARC R&M 2912, 1955. 30 pp. BIS, New York. $1.80. Tests made at Mach Numbers of 0.7 and upwards, continued past the choking Mach Number 0.764 until either the maximum fan speed was reached or the maximum available power was used, with measurements of static pressure on the airfoil surface at Reynolds Numbers of 1.4×10^6 to 5.5×10^6, and on the tunnel walls and in the stream between the airfoil and the walls at $R = 2.8 \times 10^6$. Results indicate: that when the sonic line, whose position in the stream was determined for various pressure distributions on the airfoil surface as the tunnel choked, extended halfway out from the airfoil to the tunnel walls, the tunnel Mach Number was only about 0.003 below choking value; that at speeds below choking sizable changes with Reynolds Number were observed in the pressure distribution on the airfoil surface, with the increase in Reynolds Number affecting the increase of suction just ahead of the main shock; that the shape of the pressure distribution at low Reynolds Numbers indicates the presence of a laminar boundary layer and a λ-shock; and that at higher Reynolds Numbers the pressure recovery occurs through a single shock.

AN INVESTIGATION OF THE LIFT, DRAG, AND PITCHING MOMENT CHARACTERISTICS OF AGARD CALIBRATION MODELS A AND B. C.J. Schueler and W.T. Strike. USAF AEDC TN-55-3 Feb., 1956. 49 pp. 17 refs. Tests in E-1 Gas Dynamics Tunnel (AEDC) covering the 2.0-4.0 Mach Number and 1.5×10^6 - 27×10^6 Reynolds Number range for model A, and Mach 1.7-4.0 and Reynolds Number 3×10^6 - 22×10^6 for model B. Includes measurements of the effects of model sting size on base pressure coefficients; of the skin friction using Van Driest's method; the pressure drag by applying the tangent cone and Puckett's methods; base drag by Chapman's data; with a critical analysis of specifications on model support geometry and method of fixing transition point.

MODEL SELECTION AND DESIGN PRACTICES APPLICABLE TO THE DEVELOPMENT OF SPECIFIC AIRCRAFT. D.D. Beals. 8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20-25, 1956, Paper. 29 pp. 14 refs. Discussion of the pertinent background information relative to a specific model development program, the major aerodynamic and mechanical requirements of model design, and the array of models required for a typical development program in the U.S., in terms of the aerodynamic problems of the airframe, including the influence of inlets. The program covers two phases: preliminary design, involving the assimilation of available research data; and final development providing data necessary to determine the aerodynamic performance of the configuration, including subsonic, transonic, and supersonic speed ranges and inlet and internal flow characteristics.

AGARD CORRELATION OF SPIN TESTS; A PARTICULAR STUDY ON FIAT G.82 TEST DATA. G. Gerza and G. Ciampolini. 8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20-25, 1956, Paper. 34 pp. Investigation of the spin characteristics of an aircraft with full and empty tip-tanks combined with medium aileron deflections comparing the results of full-scale flight and tunnel tests. Includes measurements of the spin recovery lag and maximum rolling angular velocity, acceleration, yawing angular velocity, pitching angular acceleration, and maximum load factor versus aileron deflections.

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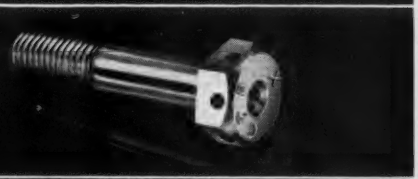

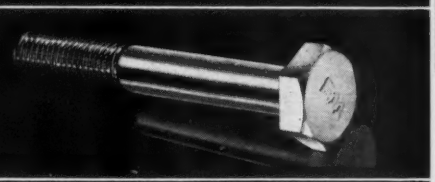

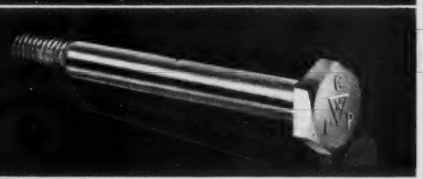

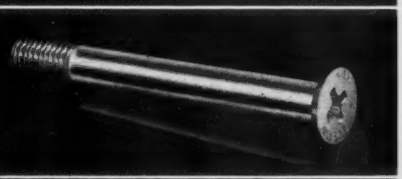

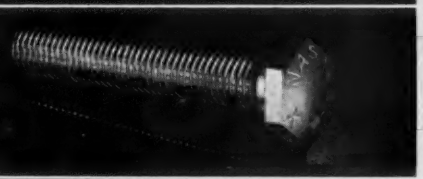

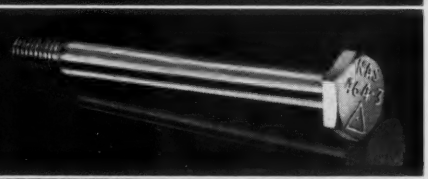

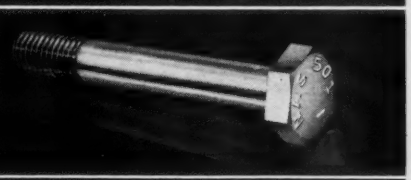

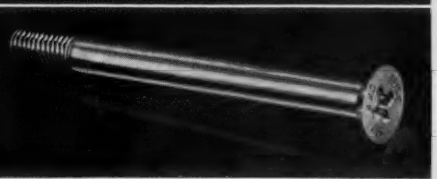

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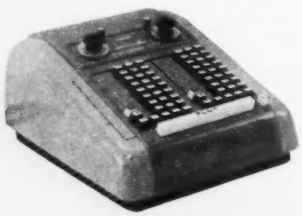

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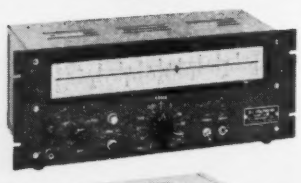

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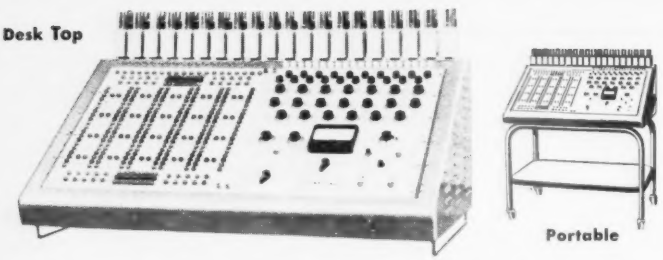

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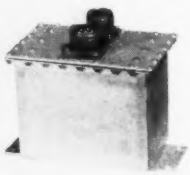

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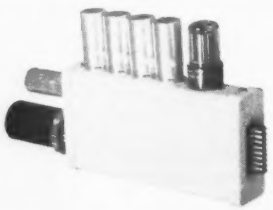

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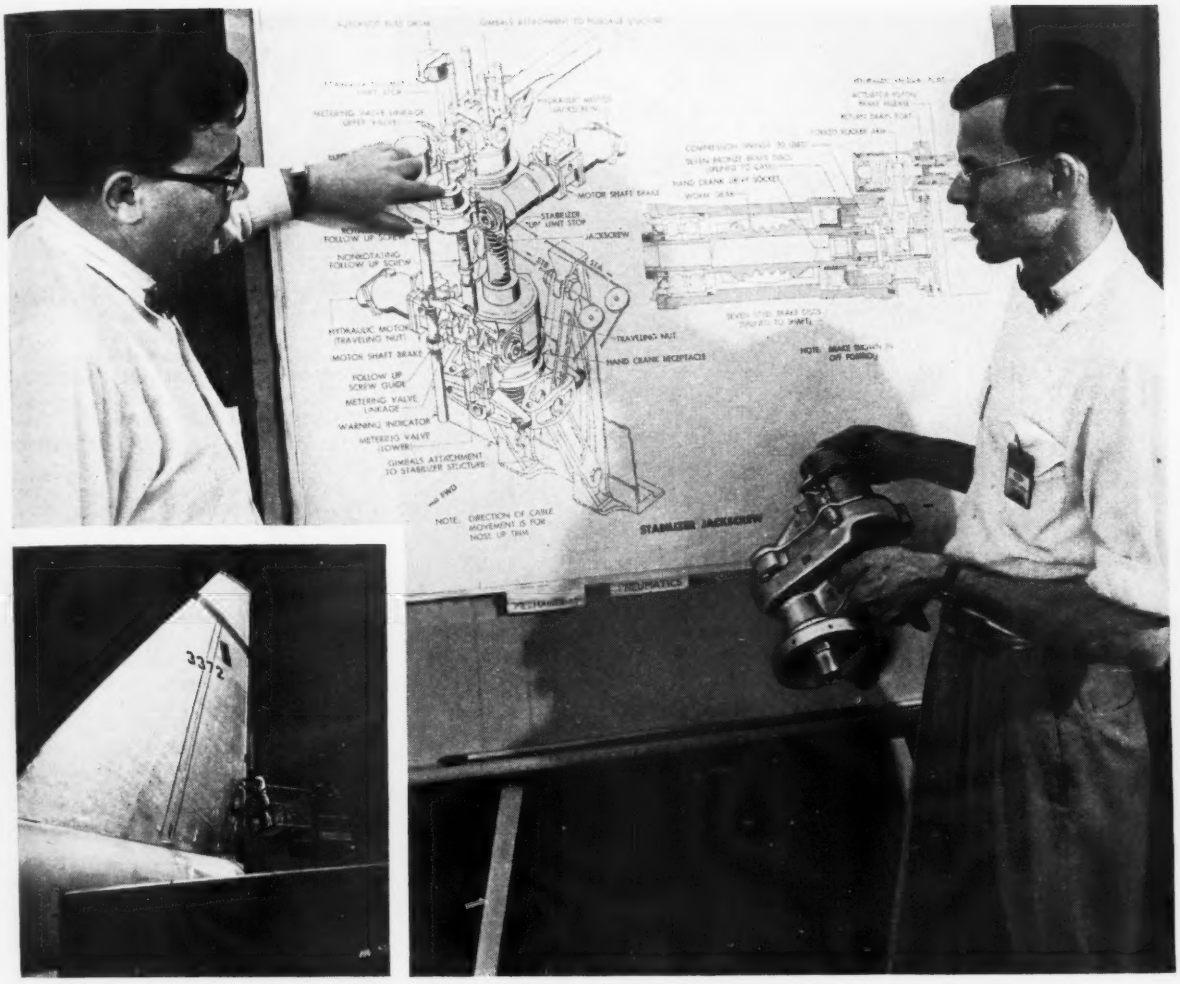

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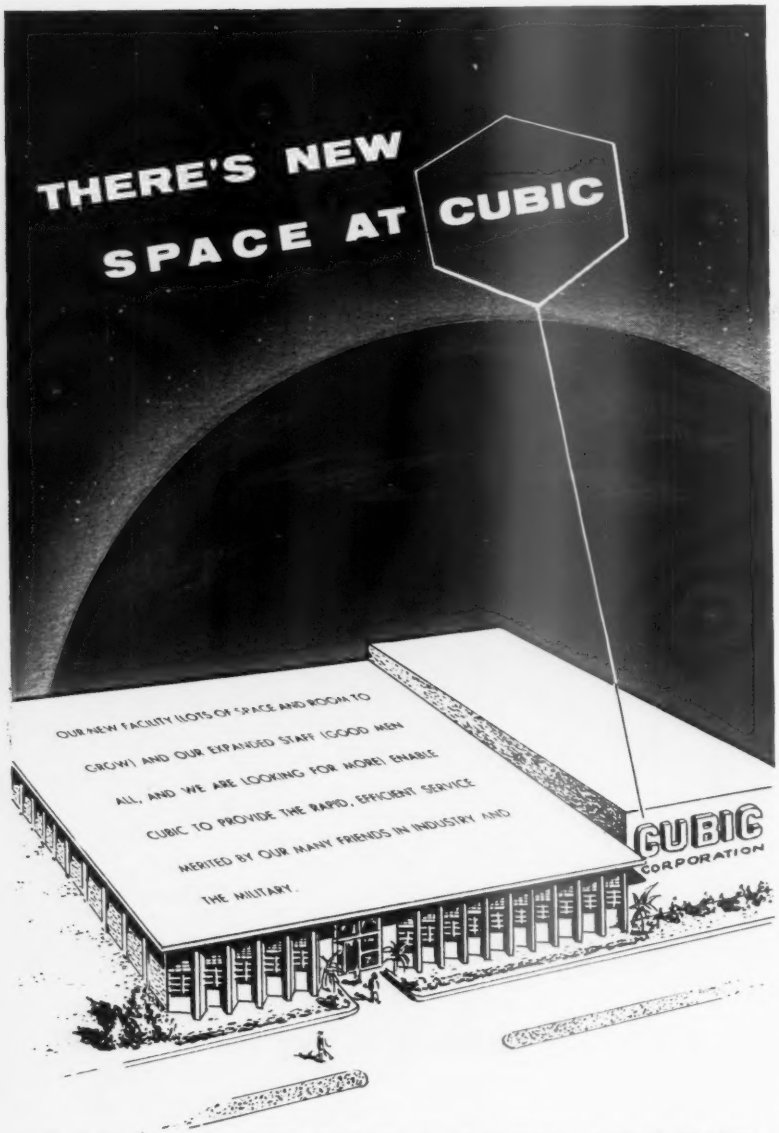
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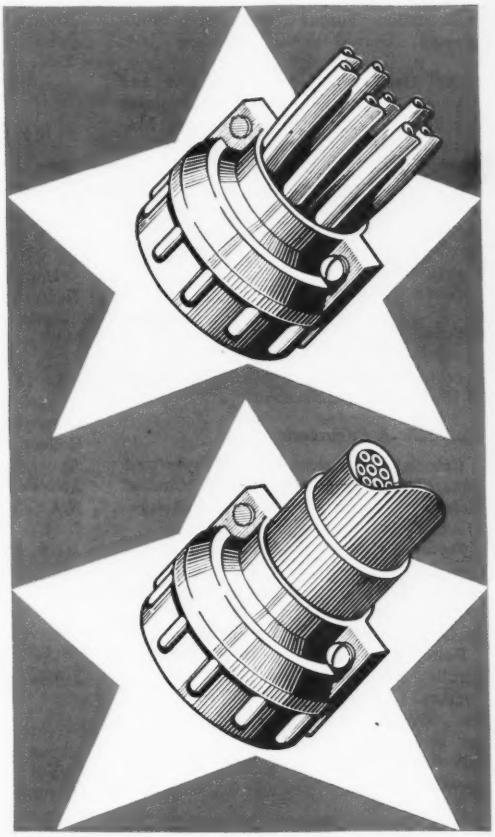

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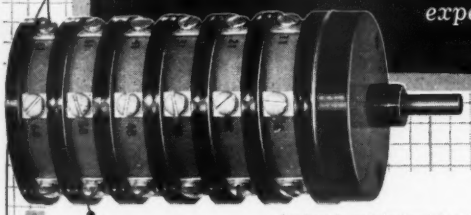

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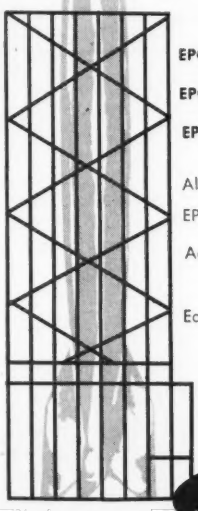

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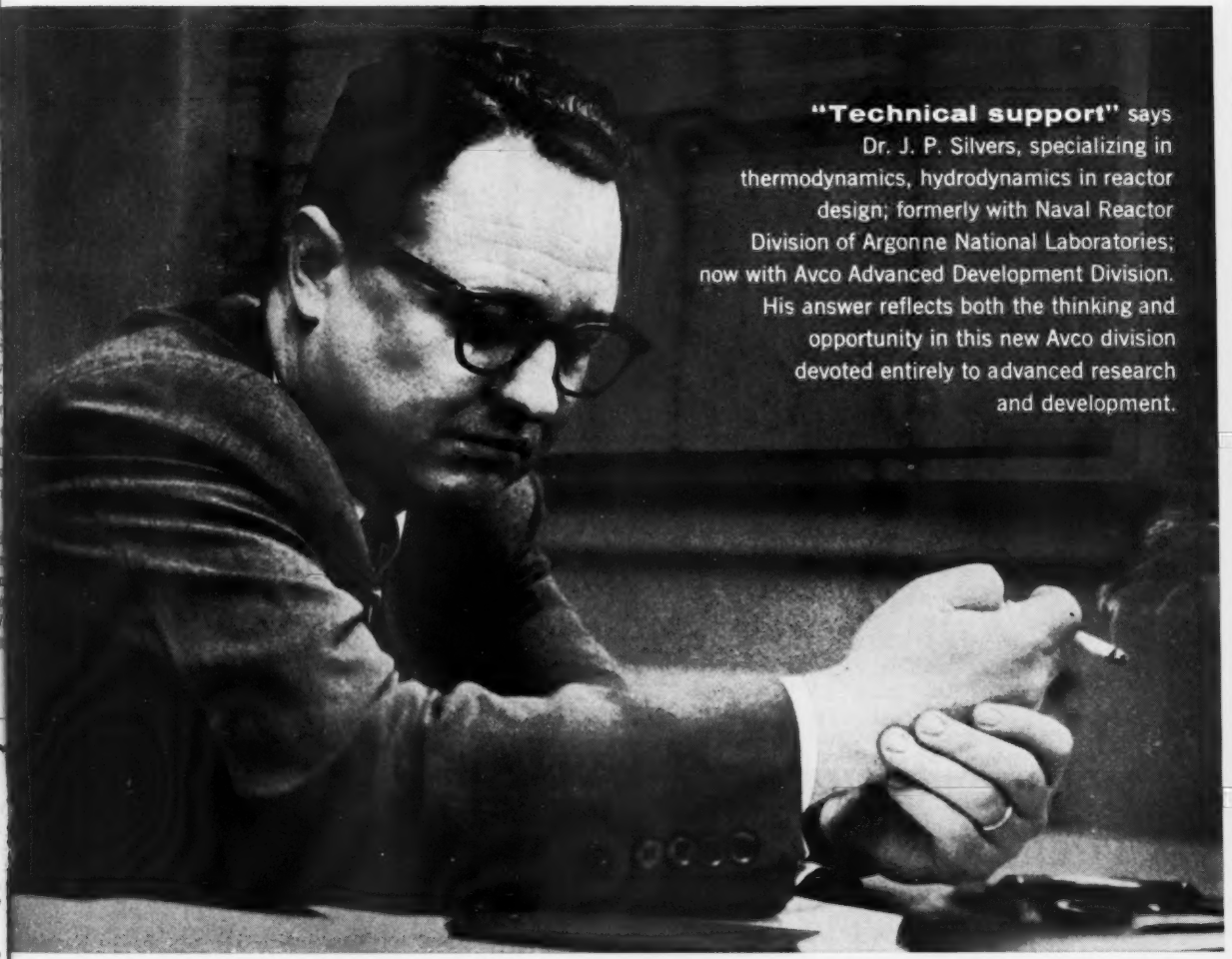

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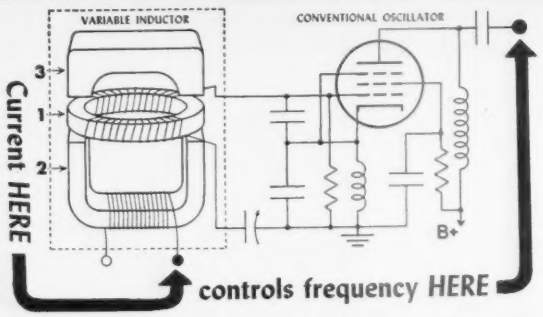

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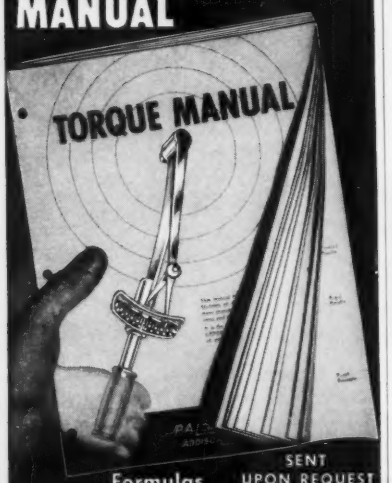

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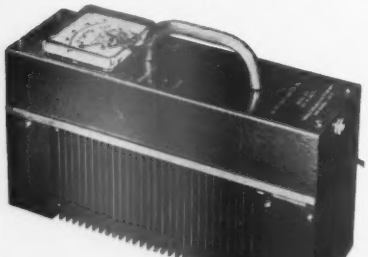

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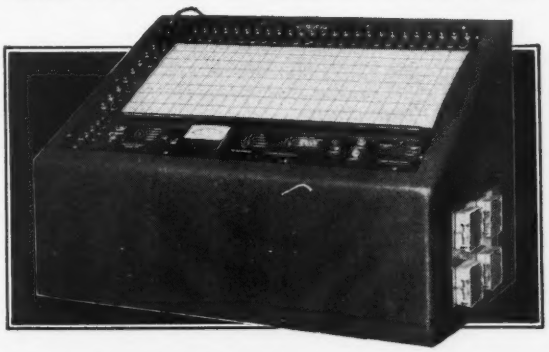

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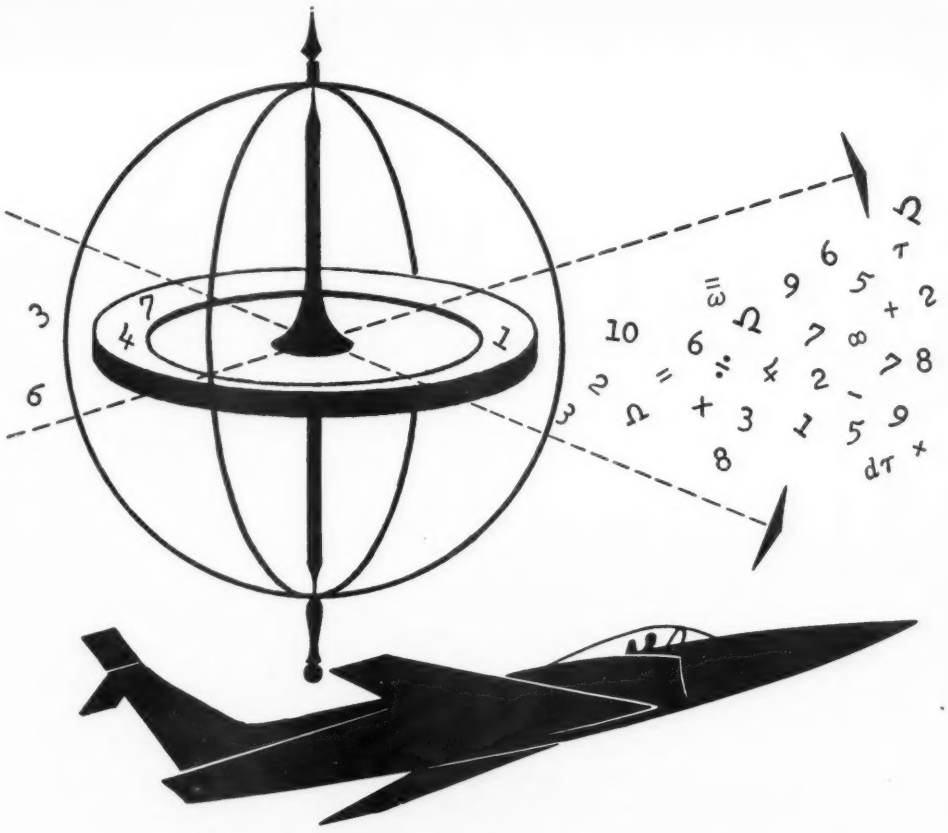

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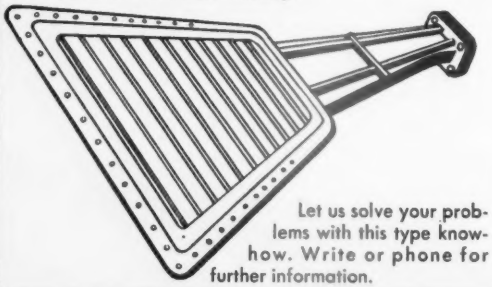
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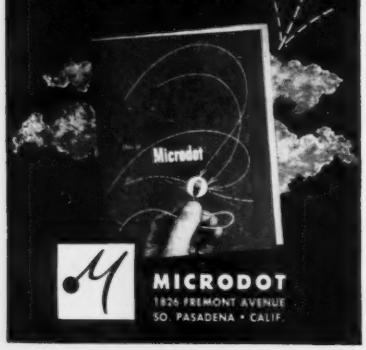

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The Flow Over a Body in a Choked Wind Tunnel and in a Sonic Free-Jet. Bernard W. Marschner. *J. Aero. Sci.,* Apr., 1956, pp. 368–376. Quantitative analysis at CIT of wall influences in the transonic region for application to closed throat wind-tunnel testing.

The High Speed Water Tunnel Three-Component Force Balance. Appendix I—**Definition of Forces and Moments.** Appendix II—**Comments on Water Tunnel Balance Design.** G. M. Hotz and J. T. McGraw. *CIT Hydrodynamics Lab. Rep. 47–1,* Jan., 1955. 39 pp. Navy-sponsored experimental investigation modifying the basic design geometry of the force balance by mounting the models on a parallelogram linkage to obtain more accurate measurements of forces on cavitating and noncavitating hydrofoils.

Preliminary Experiments on the Simulation of Gusts in a Wind Tunnel. A. M. Kuethe, J. D. Schetzer, L. C. Garby, and R. L. Roensch. *USAF TN 55–64,* Mar., 1955. 46 pp. 40 refs.

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Aeronautical Reviews — BOOKS

ACOUSTICS, SOUND, & NOISE

Ultrasonic Engineering. Alan E. Crawford. London, Butterworths Scientific Publications; New York, Academic Press Inc., 1955. 344 pp., illus., diagrs., figs. $8.00.

The purpose of this book is to collect and correlate the mass of data available on the effects and applications of ultrasonic waves and to treat in detail the basic methods of generation. The 13 chapters are accordingly divided under the headings of theory, generation, and application. The author was formerly with Mullard Research Laboratories, Ltd.

AIR TRANSPORTATION

Technical Aspects of Air Transport Management. R. Dixon Speas. New York, McGraw-Hill Book Company, Inc., 1955. 316 pp., illus., diagrs., figs. $8.50.

Written for air-line employees and students of commercial aviation, this book gives a comprehensive treatment of the operational and engineering aspects of air-line management. Beginning with a history of air-line development, it goes on to discuss first the organization, equipment, and operating costs of an air line and then proceeds to analyze these larger fields of inquiry in order to show the interrelation of various technical factors and their effect on overall efficiency, safety, and economy. Principal emphasis is placed on the equipment—its design, performance and maintenance for best returns on investment. The advent of jet- and turbine-powered transports is anticipated by inclusion of a full description of such aircraft.

Contents: (1) Historical Summary. (2) Air-line Organization. (3) Aircraft and Engines in Airline Operations. (4) Operating Costs and Revenues. (5) Aircraft Utilization and On-Time Operation. (6) Fundamentals of Flight and Performance. (7) Take-Off, Climb, and Ceiling Performance. (8) Cruise-Control Methods of Reciprocating Engines for Efficient Operation. (9) Fuel-Load Requirements. (10) Airplane Weight and Balance Problems. (11) Aircraft Maintenance and Engineering. (12) Communications and Meteorology. (13) Airports and Airways. (14) Passenger Service. (15) Cargo Operations. (16) Turbine-Powered Transport Aircraft.

AIRCRAFT

The Aircraft of the World. William Green and Gerald Pollinger. Rev. and Enl. Ed. New York, Hanover House, 1956. 211 pp., illus., diagrs. $7.95.

The first edition of this comprehensive aircraft reference manual appeared in 1954. The revision is virtually a new book. Specifications and details are given for nearly 1,000 aircraft, including 72 rotary-wing aircraft. The pictures, silhouettes, and information are of aircraft known to be flying today from the latest types such as the Chance Vought Crusader and Martin Sea Master to a variety of models dating from the late '20s and early '30s. Examples of the latter are the Westland Widgeon III and the Travel Air 4000.

Supersonic Aircraft. Roy Cross. London, Macdonald; New York, Hanover House, 1956. 63 pp., illus., diagrs. $2.50.

A pictorial record of supersonic aeronautics couched in simple, nontechnical language and illustrated with color and black-and-white photographs. Pictures and detailed descriptions encompass aircraft types from all parts of the world except the U.S.S.R. U.S. and British models predominate.

COMPUTERS

Introduction to Electronic Analogue Computers. C. A. A. Wass. New York, McGraw-Hill Book Company, Inc., 1955. 237 pp., illus., diagrs. $6.50.

An exposition of the present state of computer development covering theory, design, and applications, written by a Senior Principal Scientific Officer at the Royal Aircraft Establishment.

Contents: (1) Electronic Calculating Machines; Digital Machines, Analogue Machines, Differential Analyzers and Simulators, Elements of Electronic Analogue Computing. (2) Differential Analyzers; Use of Feedback, A Second-Order Problem, Derivatives of the Input Quantity. (3) Simple Simulators; The Mass-Spring-Friction Problem, Coupled Mass-Spring-Friction System, Coupled System with "Dash-Pot" Friction, Road Vehicle Suspension, Motion of an Aeroplane. (4) Simulators for Non-Linear Problems; A Ballistics Problem, Motion of an Electron, Road Vehicle Suspension with "Bounce," A Naval Gunnery Problem. (5) D.C. Amplifiers; Drift in the Summing Amplifier and Integrator, The Three-Stage Amplifier, The Single-Stage Amplifier, The Drift-Corrected Amplifier, Other Drift-Correction Methods. (6) Computing with Practical Amplifiers; Summation by Networks, Integration by Networks, Imperfect Reversing and Summing Amplifiers, Output Limitations, Input and Output Impedances, Imperfect Integrators, The Differentiator. (7) Non-Linear Computing Elements; Variable Mark/Space Multiplier, Other Multipliers, Dividers and Square-Root Devices, Curve Followers and Function Generators, Biased-Diode Devices, Backlash and Dead-Space Simulation, Use of Continuous Alternating Voltages, The Trigger Circuit. (8) Using Simulators; Setting up a Simulator, Initial Conditions, Simulator Studies. (9) Auxiliary Apparatus; Step and Impulse Functions, Sine-Wave Generators, Random Voltages, Presentation of Outputs, Testing and Adjustment of Elements, Power Supplies. (10) Other Classes of Simulators; Time Scales, Fast Time Scales; Repetitive Simulators, Inclusion of Components of the Real System, Network Simulators, A.C. Simulators. (11) Some Existing Computers; Repetitive Computers, GEPUS, TRIDAC. Appendix. References. Name Index. Subject Index.

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CONTROL SYSTEMS

Control-System Dynamics. Walter R. Evans. New York, McGraw-Hill Book Company, Inc., 1954. 282 pp., diagrs. $7.00.

Designed to serve as both a textbook for college courses and a reference text for practicing engineers, this volume is an exposition of the control-system calculation procedures and of the author's root locus method. The simplest problem presented here is the change in speed of a motor to a suddenly applied voltage, while the most complex is the interaction of the roll and yaw motions of an airplane. Each solution establishes a concept which permits a simpler technique to be applied to the next, more complicated problem. Throughout, emphasis is upon physical understanding of the problems as contrasted with memorizing a routine for solving particular problems. The physical picture of a solution is always developed first with the mathematics introduced later, as needed. The author is Systems Group Leader, Electromechanical Engineering Department, North American Aviation, Inc.

Automatic Feedback Control System Synthesis. John G. Truxal. New York, McGraw-Hill Book Company, Inc., 1955. 675 pp., diagrs. $12.50.

The bulk of the material in this book has been taught in a two-semester graduate servomechanism course in the Electrical Engineering School, Purdue University. The author's approach to the subject emphasizes the development of the basic theory. The reader, for the most part, is called upon to supply examples from his own experience as illustrations. The material has been presented in order that the book might serve as a textbook for students and also as a reference book for industrial engineers.

Contents: (1) Introduction. (2) Signal-Flow Diagrams and Feedback Theory. (3) Synthesis of RC Networks. (4) Root Locus Methods. (5) Synthesis through Pole-Zero Configurations. (6) Design in the s Plane. (7) Principles of Statistical Design. (8) Application of Statistical Design Principles. (9) Sampled-Data Control Systems. (10) Nonlinear Systems and Describing-Function Analysis. (11) Phase-Plane Analysis.

DIRECTORIES

U.S. Government Purchasing Directory. Small Business Administration. Rev. Ed. Washington, D.C., U.S. Government Printing Office, October, 1955. 89 pp. $0.50.

Contents: Part I: How to Use the U.S. Government Purchasing Directory. Major Military Purchasing Offices. Items and Services Purchased by the Military Procurement Offices. Local Purchases by Military Installations. Major Federal Civilian Purchasing Offices. Items and Services Purchased by the Principal Federal Civilian Procurement Offices. Part II: How Small Plants Can Sell to the Federal Gov-

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ELECTRONIC NAVIGATION AIDS

Radio Technical Commission for Aeronautics Assembly Meeting, September 29-30, 1955, Washington. Washington, D.C., RTCA, October 17, 1955. 131 pp., illus., diagrs.

Contents: RTCA's Twentieth Anniversary, J. H. Dellinger. Factors Limiting the Accuracy and Utility of Pictorial Displays: Airborne Displays, L. E. Setzer. Ground Displays, V. J. Sharkey.

The "Decision Gate" Factors in Automatic Instrument Approaches: Opening Remarks, M. B. Cahill. Automatic Path Flight Approaches from the Operator's Standpoint, E. A. Post. Automatic Flight Path Approaches under Extremely Low Visibility, R. P. Snodgrass. Reliability Factors in Autopilots, P. Noxon. CAA Views on Automatic Path Flight Approaches, E. B. Franklin. Summary of Discussion Following Symposium. Air Traffic Control Considerations, J. Smith.

Are the SC31 Communication Philosophies Still Valid: Will LF/MF, HF, VHF and UHF Voice Communication Continue to be Needed to Satisfy Future Operational Requirements, F. C. White. Extended Area Communications—ATC Centers and INSACS, J. H. Hilton. Has the Introduction of Surveillance Radar in Air Traffic Control Affected the SC31 Concept of Data Transfer and Display, S. P. Saint. Techniques for Air-Ground Visual Communication, V. I. Weihe. Summary of Discussion Following Symposium.

Can Line-Of-Sight Navigation Systems Satisfy Helicopter and Other Minimum Altitude Operational Requirements, A. Casabona. Current Development Status and Implementation Program of the ATC Radar Beacon System, S. Poritzky. Wanted: A Stationary Bench Mark for the Measurement of Altitude, B. H. Ferer. The Status of TACAN as a Common System Aid, J. F. Taylor.

Flying the Omnirange. Charles A. Zweng and John Dohm. 3rd Ed. North Hollywood, Calif., Pan American Navigation Service, 1955. 153 pp., illus., diagrs. $4.00.

A pilot's guide to the VHF omnidirectional radio range, distance-measuring equipment, and the course-line computer. From take-off to landing, the procedures of cross-country navigation are presented in straightforward terms. A second edition of this guide was issued in 1952.

ELECTRONICS & ELECTRICTY

Sixth Annual Electronic Components Conference Proceedings, Los Angeles, May 26-27, 1955. Los Angeles, 1955 Electronic Components Conference, 1955. 127 pp., illus., diagrs., tables. $4.50.

The eight sessions of the conference are represented by 54 papers under the following subject divisions: Power Transistors and High Frequency Transistors; Materials and Magnetic Components; Component Application and Reliability; Transistor Reliability and New Semi-Conductor Devices; Microwave Devices and Electron Tube Reliability; Vacuum Tubes I; Vacuum Tubes II; Resistors and Capacitors.

Report of the Conference on Reliability of Electrical Connections; April 15-16, 1954, Illinois Institute of Technology. Sponsored by the Engineering Department, Radio-Electronics-Television Mfrs. Assn., with cooperation of the Aircraft Industries Association. New York, RETMA Engineering Office, 1955. 76 pp., diagrs., tables. $5.00.

Contents: Theory and Uses of Soldering Fluxes, Clifford L. Barber. Soft Solder Alloys, Martin A. Boyle, Jr. Methods of Removing Enamel and Formex from Wire in the Electronic Industry. G. W. Cavanaugh. Surfaces for Soldering, E. R. Bowerman. The Application

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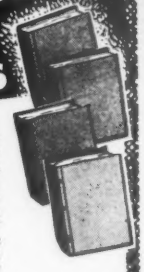

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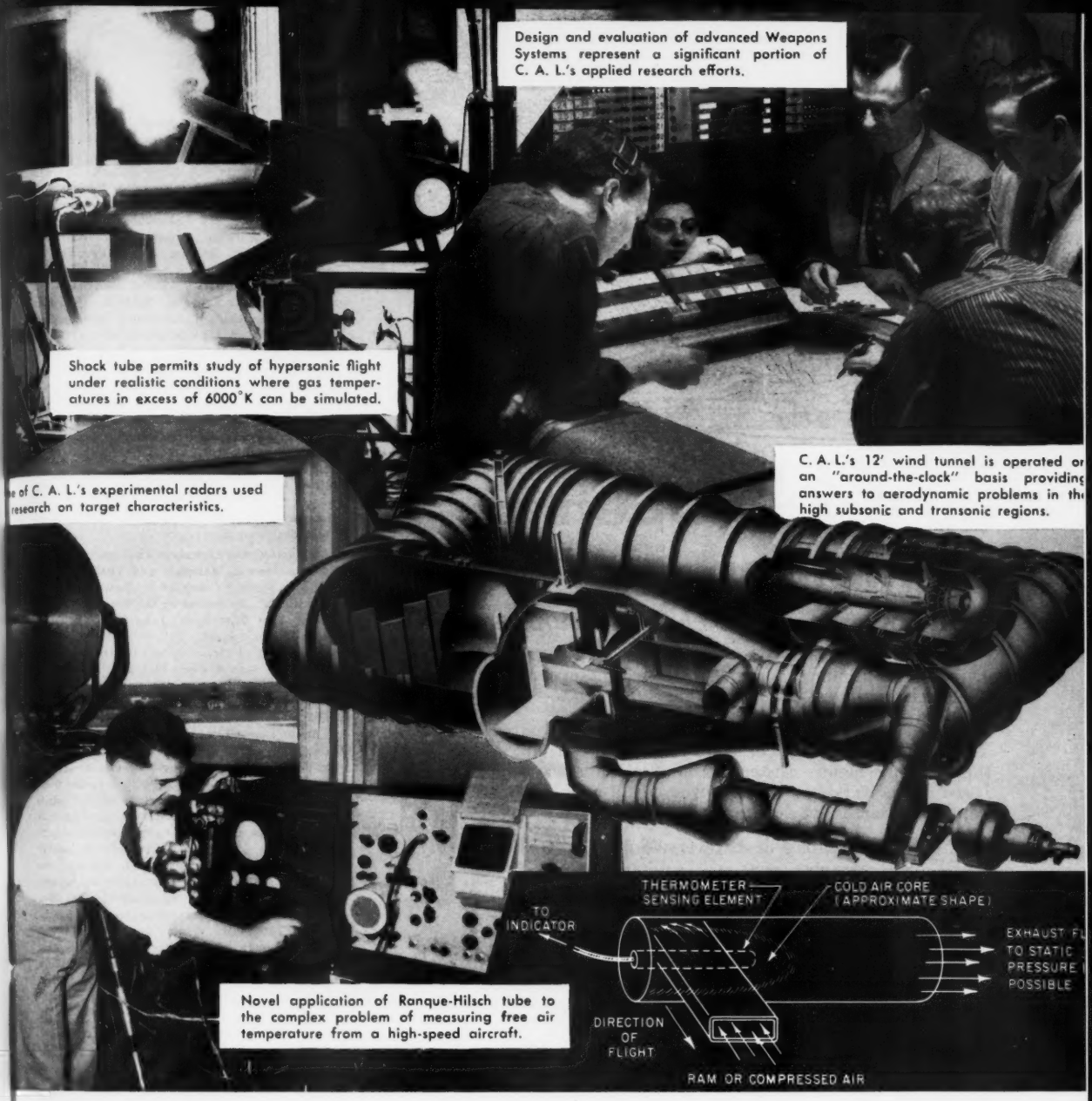
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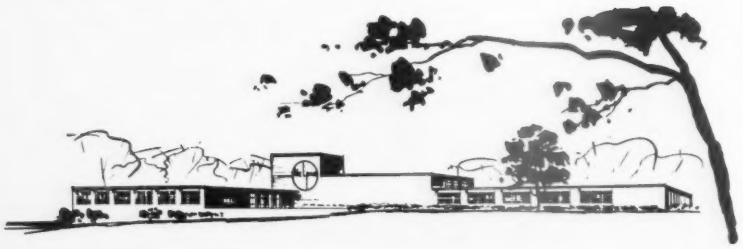

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Transistor Electronics. Arthur W. Lo, Richard O. Endres, Jakob Zawels, Fred D. Waldhauer, and Chung-Chih Cheng. Englewood Cliffs, N.J., Prentice-Hall, Inc., 1955. 521 pp., diagrs. $12.

Written for advanced and undergraduate and graduate students, this book is designed to give a basic working understanding of transistor operation, circuit analysis, and practical circuit design. Over 300 illustrations enhance its usefulness as a reference and as a guide for the electronics design engineer.

Abstracts of the Literature on Semiconducting and Luminescent Materials and Their Applications, 1954 Issue. Compiled by Battelle Memorial Institute; Sponsored by the Electrochemical Society, Inc. New York, John Wiley & Sons, 1955. 200 pp. $5.00.

The growth of the solid-state electronic device industry has been so rapid that keeping up with the contributions from the field has become an almost hopeless task. In order to keep interested personnel up to date, the Electrochemical Society initiated a long-range project last year to publish annually organized abstracts of the literature on semiconducting and luminescent materials and their applications. In this second issue, both foreign and domestic publications are included, and an attempt has been made to present in each abstract the most important experimental results or conclusions. Thus, the necessity for the reader to obtain the original article is minimized by including this information. By supplying subject and author indexes, the compilation serves as a fairly complete desk reference in this area of technology. The entire volume contains over 750 abstracted articles on the following topics: Germanium, Silicon, Carbon, Boron, Selenium and Tellurium, Intermetallics, Oxides, Sulfides, Halides, Organics, Fluorescence and Phosphorescence.

Electronic Engineering. Samuel Seely. New York, McGraw-Hill Book Company, Inc., 1956. 525 pp., diagrs., figs. $8.00.

Much of the material in this book has been used in courses in electronic circuits and applications at Syracuse University, where the author is Professor and Chairman of the Department of Electrical Engineering. Discussed in detail are a large variety of electronic circuits, important in such diverse fields as radar, television, electronic control and instrumentation, and computers. Emphasis is placed on the physical and mathematical analyses. Examples and problems are used to relate the theoretical developments with practical situations. Although this book, together with its companion volume *Radio Electronics*, is a revision and enlargement of the author's *Electronic Tube Circuits*, both books are independent, self-contained texts.

Basic Processes of Gaseous Electronics. Leonard G. Loeb. Berkeley, University of California Press, 1955. 1012 pp., illus., diagrs., tables. $13.50.

Leonard B. Loeb is Professor of Physics at the University of California, Berkeley. His book deals with the basic atomic, electronic, molecular, and kinetic mechanisms leading to the electrical behavior of gases. The subjects considered in detail are: ionic mobilities, diffusion of carriers in gases, velocities of electrons in a field, formation of negative ions, electrical conduction in gases, ionization by collision of electrons—the first Townsend coefficient, and the second Townsend coefficient. Detailed mathematical anal-

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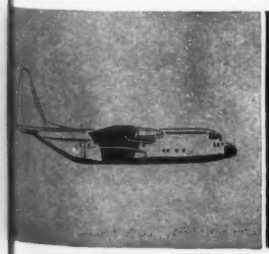

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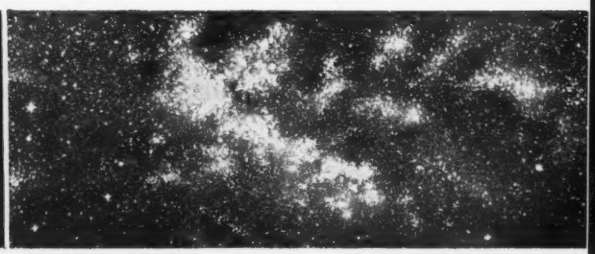

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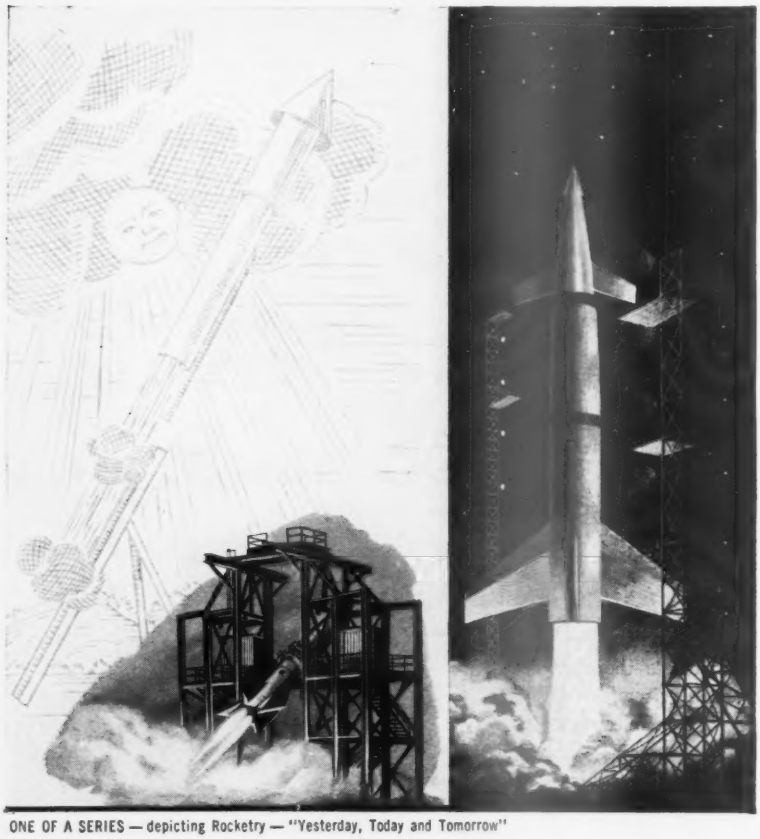

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yses are not included, but the approach is sufficiently analytical to indicate the physical theory underlying the study. The book is directed primarily to the physicist, chemist, or engineer. The Office of Naval Research gave much assistance in making this comprehensive summary available.

Electronic Transformers and Circuits. Reuben Lee. 2nd Ed. New York, John Wiley & Sons, Inc., 1955. 360 pp., illus., diagrs. $7.50.

This second edition of a book that first appeared in 1947 contains new sections on magnetic amplifiers, pulse circuits, reactor surges, toroid cores, r-f power supplies, wide-band transformers, and charging chokes. Coverage of the material is general with only a brief treatment for the different aspects of the subject.

Switching Relay Design. R. L. Peek and H. N. Wagar. New York, D. Van Nostrand Company, Inc., 1955. 478 pp., illus., diagrs., tables. $9.50.

This book is an analytical approach to the design relations governing the performance of switching relays. It covers both the mechanical contacting system and the actuating electromagnet in an integrated treatment of the dynamic performance. The analytical procedures developed can be used to evaluate the characteristics of an existing relay or to determine optimum conditions for a proposed design.

Practical Electroacoustics. Michael Rettinger. New York, Chemical Publishing Co., Inc., 1955. 271 pp., 39 refs. $10.

The purpose of this book is to present engineering information on electroacoustics, covering both basic principles and practical applications. The author, who is with the Engineering Department, RCA Victor Division, Radio Corporation of America, is concerned chiefly with the description and analysis of the essential units of audio-communication equipment—microphones, moving-coil loudspeakers, mixers, studios, magnetic recording devices, as well as certain related subjects—but does not cover certain subjects that are extensively treated elsewhere or are too little developed to be of practical use. Hence, only brief treatment has been accorded amplifiers and acoustic measurements, and omitted entirely are descriptions of transient-response evaluations of electroacoustic transducers and the phase-delay distortions of such devices. A list of 29 books and articles is appended.

Modern Oscilloscopes and Their Uses. Jacob H. Ruiter, Jr. New York, Rinehart & Company, Inc., Seventh Printing, May, 1955. 326 pp., illus., diagrs. $6.00.

Starting with a discussion of what the oscilloscope is, what it consists of, and examples of the various functions it performs, the book progresses to the operation of the cathode-ray tube; then the operation of the oscilloscope itself, together with its other components is described. The interpretation and use of basic patterns obtained with the oscilloscope are explained by means of carefully prepared drawings. Applications in industry, in education, and in the servicing of radio and television are also indicated. The author is on the staff of the Allen B. Du Mont Laboratories, Inc.

FUELS & LUBRICANTS

ASTM Standards on Petroleum Products and Lubricants (With Related Information). Prepared by ASTM Committee D-2 on Petroleum Products and Lubricants. Philadelphia, American Society for Testing Materials, November, 1955. 954 pp., diagrs., tables. $6.50.

MATHEMATICS

Methods of Mathematical Physics. Sir Harold Jeffreys and Bertha Swirles (Lady Jeffreys). 3rd Ed. New York, Cambridge University Press, 1956. 714 pp. $15.

The present edition, which succeeds the second edition of 1950, does not give evidence of substantial addition or of extensive revision. Errors and misprints have been corrected; some theorems have been stated more explicitly; a few proofs have been added, and some have been

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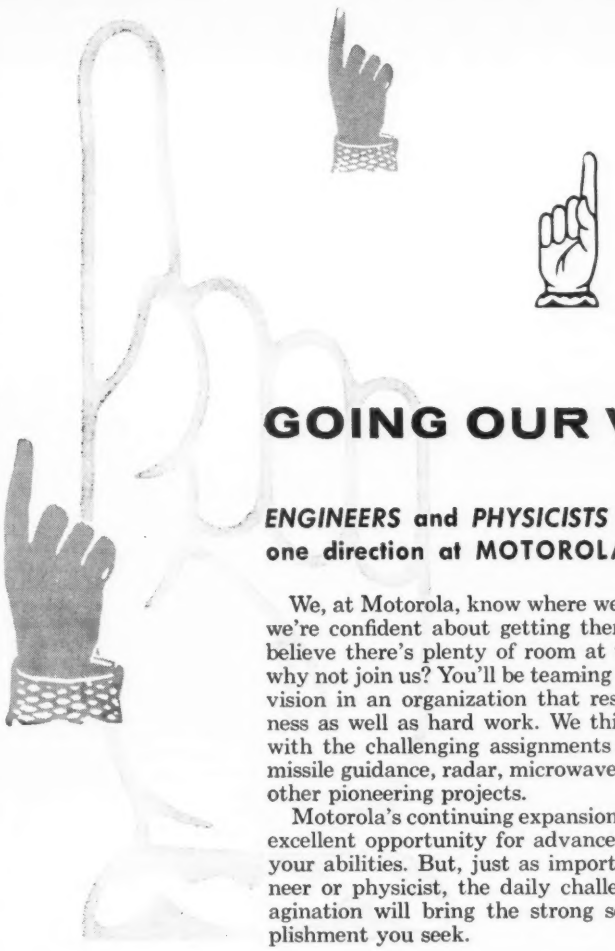

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shortened. Some specific changes include an elementary proof of the theorem of bounded convergence for Riemann integrals, which appears in the notes; the improvement of the proof of Poisson's equation in Chapter 6, "Potential Theory"; a more detailed discussion of the Airy integral for complex argument in Chapter 17, "Asymptotic Expansions"; conditions for uniformity of approximation for asymptotic solutions of Green's type for complex argument; and remarks on the analytic continuation of the solutions and a note applying them to the parabolic cylinder functions which are added to Chapter 23, "The Confluent Hypergeometric Function."

Spheroidal Wave Functions, Including Tables of Separation Constants and Coefficients. J. A. Stratton, P. M. Morse, L. J. Chu, J. D. C. Little, F. J. Corbató. New York, The Technology Press of M.I.T., and John Wiley & Sons, Inc., 1956. 613 pp., tables. $12.50.

This book has been written for the electrical engineer and physicist. Its contents are best described as a brief bibliography, a minimum of text (63 pp.), and a maximum of tables (548 pp.). The work deals with those spheroidal wave functions appropriate for prolate or oblate spheroidal boundaries. It defines certain standard forms of their solution which are useful in practical problems, and it displays a collection of formulas giving the important mathematical properties of these functions. Included also is a set of tables from which values of the solutions can be obtained for the more interesting ranges of the variables. These tables contain the series of coefficients together with some of the separation constants. All the numbers contained in the tables were determined by the high-speed electronic digital computer Whirlwind I at M.I.T. They were computed, tabulated, and printed automatically, thus permitting a degree of reliability never before achieved in an undertaking of this nature with functions of this complexity.

Geometry of Four Dimensions. Henry Parker Manning. New York, Dover Publications, Inc., 1956. 348 pp., diagrs. $1.95.

This is a complete, unabridged reproduction of a work first published in 1914. Manning's treatment serves as a concise introduction to a branch of modern mathematics now in application as part of mathematical physics (algebra, analysis, relativity). The treatment is based mostly on Euclidean geometry, although, in some cases such as hyperplanes at infinity, non-Euclidean geometry is used.

METALS & ALLOYS

Principles of Physical Metallurgy. Morton C. Smith. New York, Harper & Brothers, 1956. 417 pp., illus., diagrs. $6.00.

Alloy Series in Physical Metallurgy. Morton C. Smith. New York, Harper & Brothers, 1956. 338 pp., illus., diagrs. $6.00.

These two companion volumes have been prepared and published together. They provide an up-to-date presentation of the fundamentals of metal behavior and the effects of composition and heat treatment upon the structures and properties of metals and their alloys. The author is an Alternate Group Leader of the Los Alamos Scientific Laboratory, University of California. His contention is that handbooks, which are concerned with *how* metals behave under specific conditions, leave unenlightened the area as to *why* metals behave as they do. These treatises are an attempt to develop and to present a science of metal behavior as an integrated, consistent, and satisfying chain of reasoning, extending from the familiar principles of physics and chemistry to the observed behavior of the industrial metals and their alloys. *Principles of Physical Metallurgy* begins with the necessary background in physics, chemistry, and thermodynamics. It then discusses in detail the crystallography, crystal structures, and crystal mechanics of metals, with an extensive treatment of crystal imperfections, deformation behavior, and the general effects of elevated temperatures. *Alloy Series in Physical Metallurgy* begins where the *Principles* volume ends. It systematically discusses the effects of composition, heat treatment, and forming procedures upon the microstructures and properties of metals and alloys. Beginning with the phase rule and binary constitutional diagrams in general, it considers the solidification and solid-state reactions commonly encountered in metallic systems. It discusses both the equilibrium behavior of such systems and the departures from equilibrium that can be expected in them. Full chapters are devoted to steels, to the cast irons, and to ternary and higher alloys. Interrelations of thermal treatment, microstructures, and properties are emphasized throughout. Both books are intended as reference volumes for metallurgical engineers in the field and as basic texts for the two-semester college courses in physical metallurgy in the metallurgical engineering course.

POWER PLANTS, ATOMIC

Thermal Power from Nuclear Reactors. A. Stanley Thompson and Oliver E. Rodgers. New York, John Wiley & Sons, 1956. 229 pp., diagrs., tables. $7.25.

This book on atomic reactors is written for the mechanical engineer. On the assumption that it will be read by persons who are not familiar with all of the subjects involved, each discussion is begun at a level that is common to all branches of engineering. Stressing a design approach, the work discusses problems of reactor development which confront the engineer in atomic power plants. Engineering problem-solving techniques such as numerical and dimensional analysis are applied to these problems, and workable design criteria are evolved. Some of the problems of reactor development treated in this manner are thermal stresses, transient behavior of reactors, and distribution of gamma rays and neutrons. A brief bibliography supplements each chapter. The authors are both connected with Studebaker-Packard Corporation—A. Stanley Thompson as Chief Engineer of the Nuclear Power Department and Oliver E. Rodgers as Assistant General Manager in Charge of the Government and Industrial Products Division.

RESEARCH

National Science Foundation, Fifth Annual Report, Fiscal Year 1955. Washington, D.C., U.S. Government Printing Office, 1955. 159 pp., diagrs. $0.50.

The Fifth Annual Report also presents a summation of activities for the last 5-year period. The important problems of the Foundation are described together with what has been accomplished with respect to them and what is in process towards the solution of some of them. The appendixes include a listing of research support programs, grants, graduate fellowships, and publications of the Foundation.

Annual Report, 1954-1955. National Academy of Sciences—National Research Council, Division of Engineering and Industrial Research, Washington, D.C., 1955. 50 pp.

ROTATING WING AIRCRAFT

Helicopters in Korea, July 1, 1951—August 31, 1953. U. S. Army, Far East Command. Fort Eustis, Va., U.S. Army Transportation School, April, 1955. 96 pp., illus., diagrs., tables.

This monograph presents a detailed account of helicopter operations by the United States Army in Korea from July 1, 1951 to August 31, 1953. It embraces not only the employment of organic helicopters, ambulance helicopters, and cargo helicopters but also the problems pertaining to their maintenance and logistic support. Historical material is discussed under four separate headings: (1) the early development of the helicopter program in Korea; (2) their achievements as recorded from actual operations including evacuation, resupply, and troop deployment; (3) the major problems encountered in the helicopter program and their eventual solutions; (4) the evaluation of rotary-wing aircraft as a result of their extensive utilization in Korea. There are 73 illustrations in this book which is issued as a special text and approved for resident and course instruction at the Fort Eustis, Va., Transportation School.

STRUCTURES

Mathematical Theory of Elasticity. I. S. Sokolnikoff. 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1956. 476 pp., diagrs. $9.50.

Initially published in 1946 and based upon lectures given at the Graduate School of Brown University and the University of California, this book is a revised and greatly expanded edition. Most of the material in the last three chapters had no counterpart in the first edition. The book attempts to present several aspects of the theory of elasticity from a unified point of view and to indicate, along with the familiar methods of solution of the field equations of elasticity, some newer general methods of the two-dimensional problems. One omission should be pointed out—because of space limit there is no discussion of the theory of shells.

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Aeronautical Engineer—To teach aerodynamics, airplane design, and applied mechanics. Should have M.S. degree and some industrial experience. Salary and rank according to qualifications. Apply: Department of Mechanical Engineering, Oregon State College, Corvallis, Ore.

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The number preceding the notiec represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Engineers—Scientists—The Armament Center at Eglin Air Force Base, Fla., has recently been given the responsibility for the development of aerial munitions—including guns, bombs, rockets, fuzes, guided-missile warheads, and related equipment—exclusive of nuclear weapons. Positions in fields covered by this responsibility have now become open and are currently being filled. Our openings lie mainly for those qualified for Civil Service Grades between and including GS-5 and GS-14. The personnel most urgently needed are physicists, mechanical engineers, ballisticians, and especially electronic engineers. Applicants chosen in these grades may expect to receive between $3,670 and $10,320 annually. Those interested in applying should submit Standard Form 57, Application for Federal Employment, to: Civilian Personnel Office, 3201st Air Base Wing, Eglin Air Force Base, Fla.

Engineers—Fairchild Engine Division of the Fairchild Engine and Airplane Corporation, Deer Park, Long Island, N.Y. Diversified engineering positions are available involving engine research, design, design and performance analysis, test engineering, compressor and turbine design, control systems, and other engineering operations associated with the general field of design and development of gas-turbine power plants. These opportunities result from expanded programs in a new plant and gas-turbine laboratory. Send résumé to: Felix Gardner, Fairchild Engine Division, Deer Park, Long Island, N.Y.

Professors—The Institute of Technology, USAF, has several vacancies for qualified professors or engineers to teach on a graduate and undergraduate level in aeronautical, mechanical, chemical, and production engineering. Employment will be effected in accordance with Civil Service regulations. Grade levels range from GS-9, $5,440 per annum, to GS-13, $8,990 per annum. Applications should be made to the Dean, Resident College, Institute of Technology, USAF, Wright-Patterson AFB, Ohio.

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